

The Bush River Watershed
Water Quality Monitoring Program
Final Report

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Introduction

Over the past several decades, the region surrounding Chesapeake Bay has experienced rapid population growth. Nowhere has this growth been more evident than in Harford County where the population has grown from 77,000 in 1960 to 169,000 in 1988. Concurrent with this growth comes added pressure on services, facilities, and natural resources. Some of the most notable and obvious impacts are brought to bear against water resources. Typical of areas which develop rapidly are stormwater runoff problems, erosion and sedimentation due to urbanization, and higher nutrient loads in streams due to runoff, overfertilization of lawns, and leaking septic systems and sewerage lines. Turbidity levels increase, due to siltation and increased algal growth. Biological diversity and abundance decrease as oxygen levels drop and the overall health of the observed stream declines.

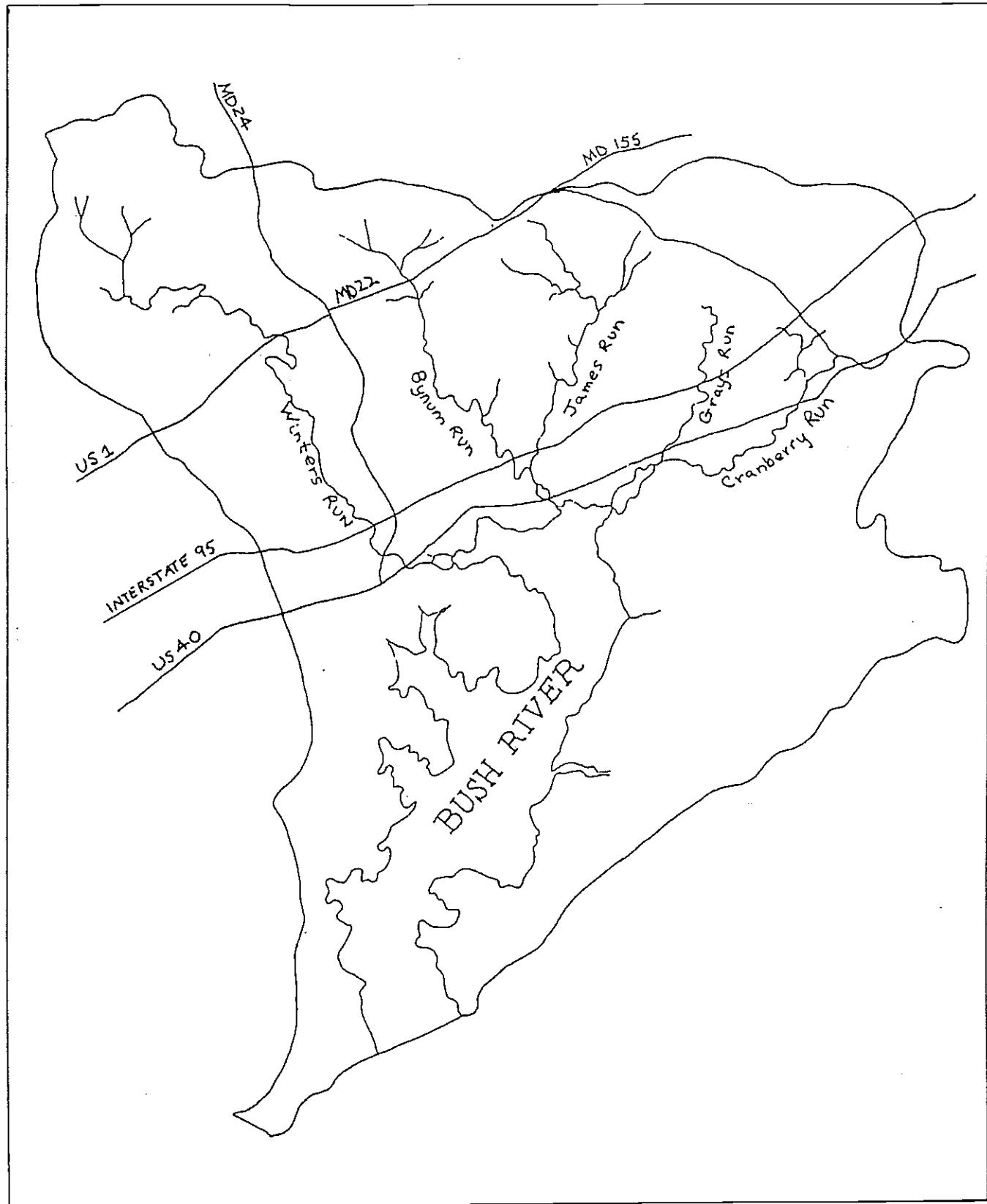
These trends are not only observable when more people congregate an area, but also where intensification of agriculture overtaxes land capacities. Cultivating too close to streams, improper tillage, overfertilization of crops, improper handling of animal waste, and pesticide abuse can all degrade stream quality.

There can be little doubt that the water quality in Harford County's streams and adjacent waters in the Bay have declined in recent decades. Where crabs yielded a bountiful

harvest from the Bush River during the 1980's, they are now uncommon. The Maryland Darter, a small fish once commonplace in the clear riffles of Deer Creek and Gasheys Creek, is now critically endangered. Trout no longer inhabit streams in which they used to abound. Reports of visibility to a depth of twelve feet in the Bush River are now replaced by complaints of muddy water, high bacterial counts, and closed swimming beaches.

The questions that must be posed are, "What are the primary factors degrading our waters?", and "What can be done to alleviate these pressures?" Are the impacts predominantly agricultural or domestic? What were precultural conditions?

These questions are difficult to address since very limited data are available from past studies and no systematic study has been carried out over a long period of time. It is our hope that the data and information presented here will provide not only a comparison for what past data are available, but will provide the first systematically derived baseline information for water quality parameters measured within the Bush River drainage system.



Bush River Watershed Area

Key to Sampling Sites

Winters Run

- 1 Pleasantville Rd.
- 2 Carrs Mill Rd.
- 3 Bel Air Rd.
- 4 Ring Factory
- 5 Singer-Winters Run Rd.
- 6 Route 40

Bynum Run

- 7 Route 23
- 8 Bynum Ridge Rd.
- 9 Churchville Rd.
- 10 Wheel-Patterson Mill Rd.
- 11 Route 7

James Run

- 12 Graftons Lane
- 13 James Run Rd.
- 14 Route 543
- 15 Route 7
- 16 Route 40

Grays Run

- 17 James Run Rd.
- 18 Carsins Run Rd.
- 19 Route 7
- 20 Route 40

Cranberry Run

- 21 Aldino-Stepney Rd.
- 22 Bush Chapel Rd.
- 23 Old Philadelphia Rd.
- 24 Spesutia Rd.

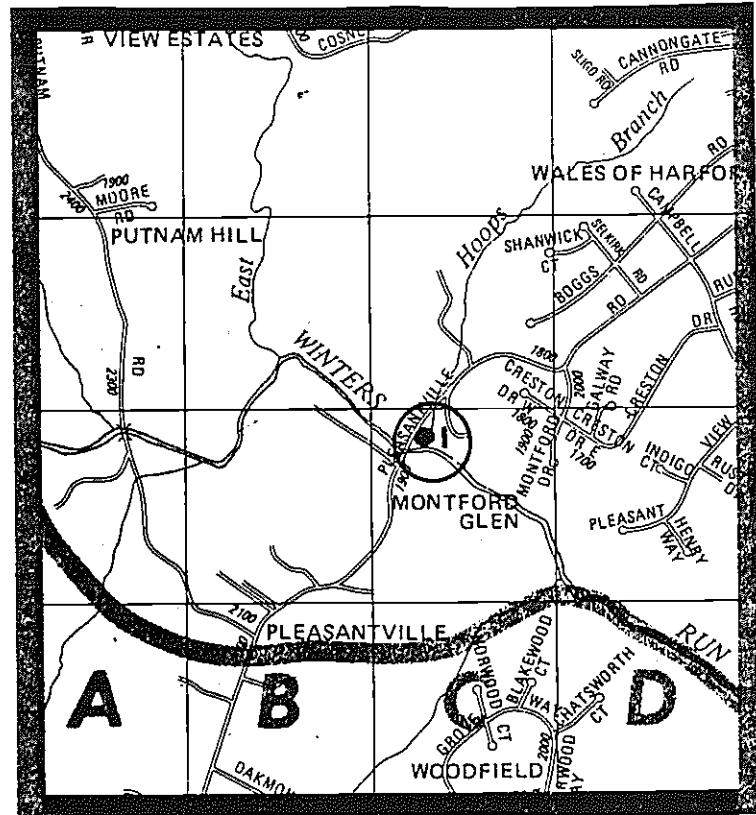


Fig. 1

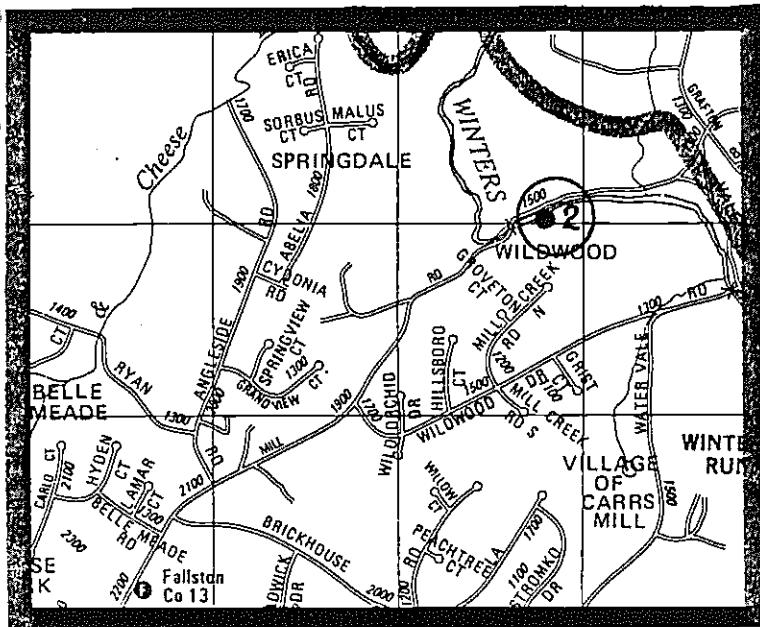


Fig. 2

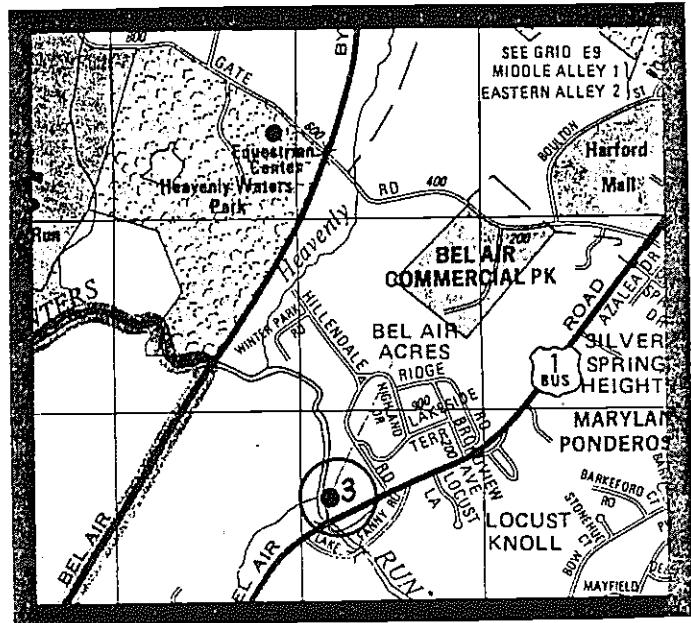


Fig. 3

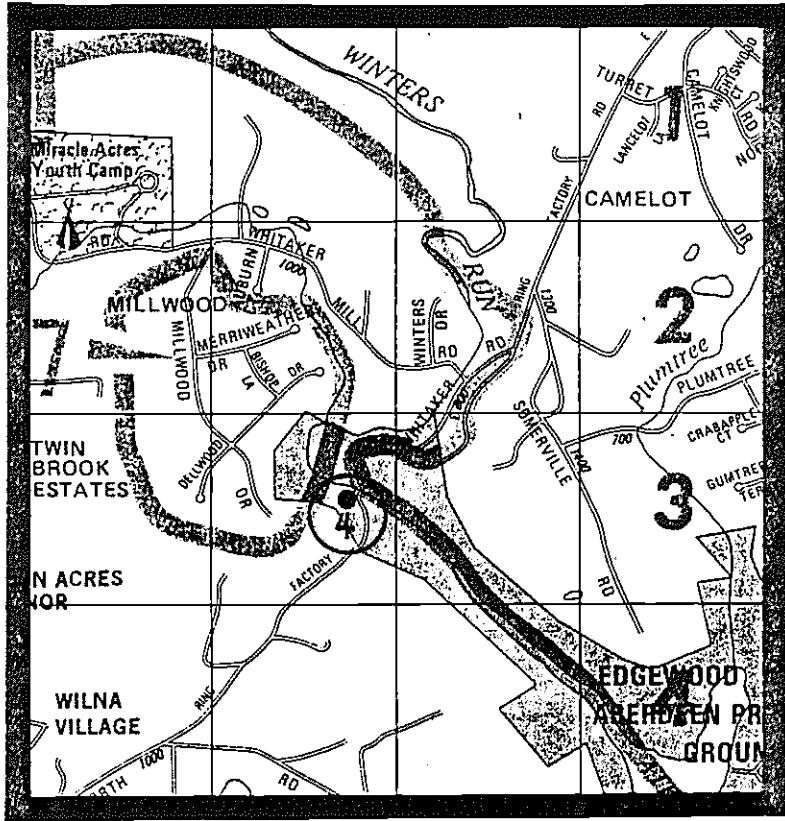


Fig. 4

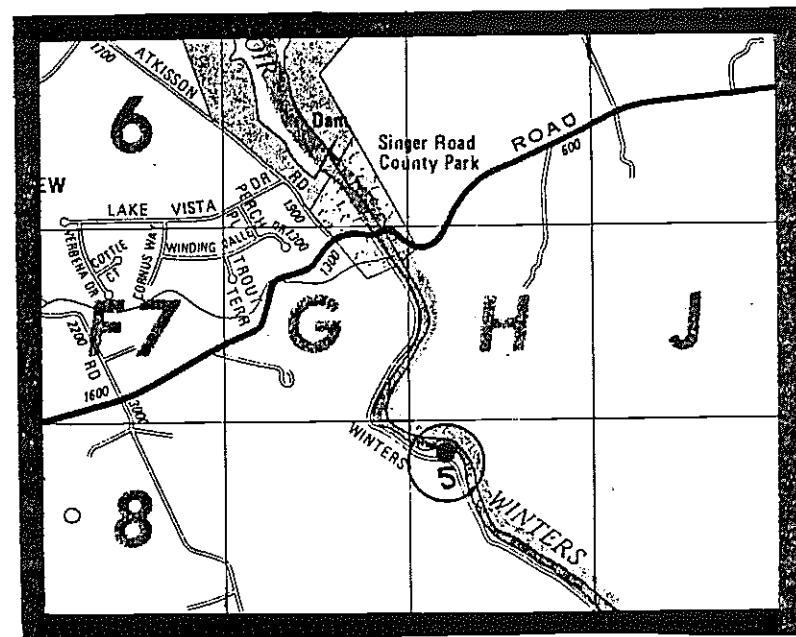


Fig. 5

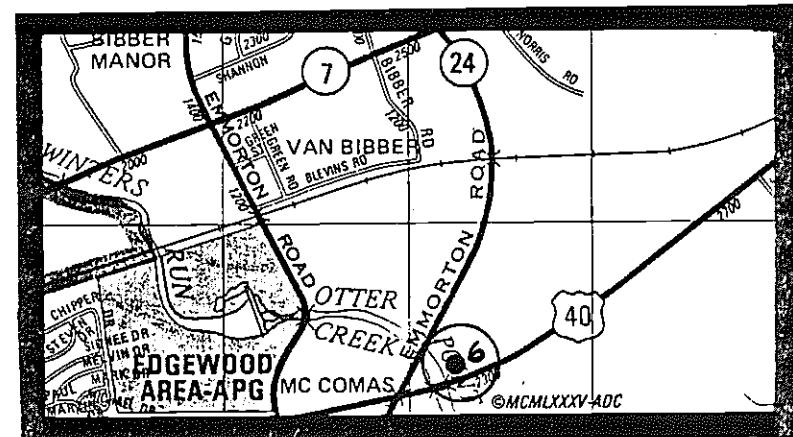


Fig. 6

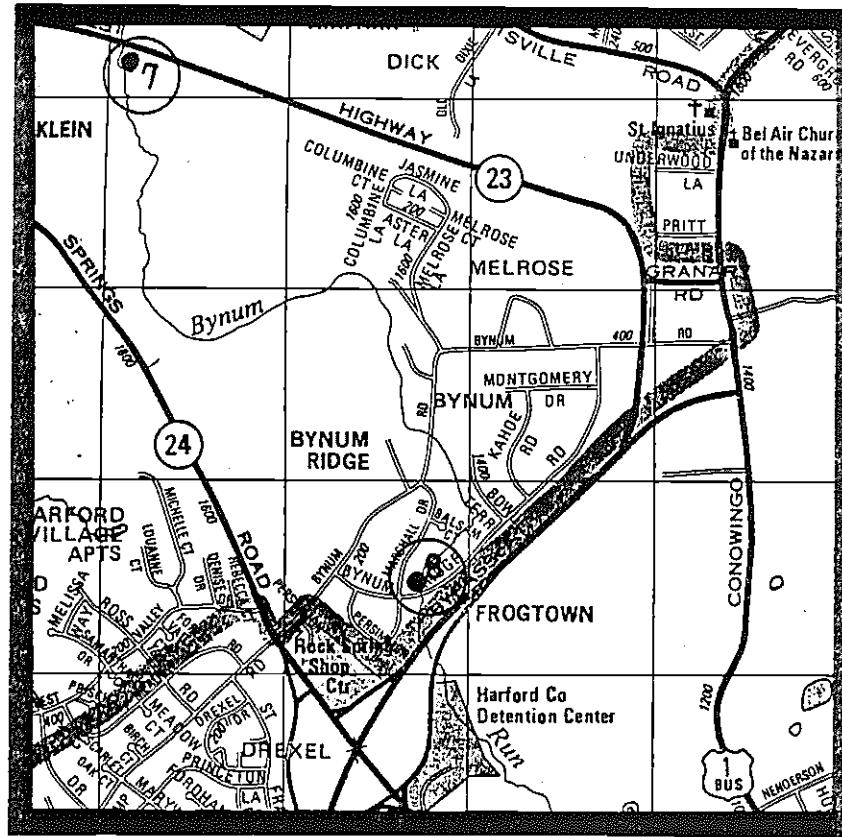


Fig. 7

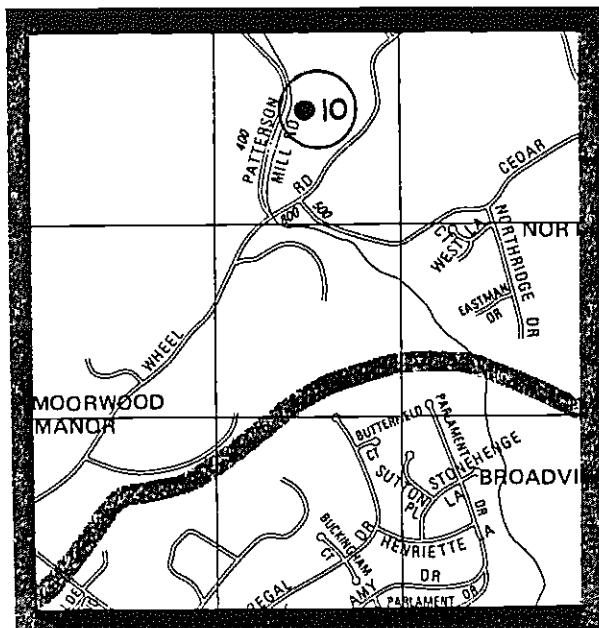


Fig. 8

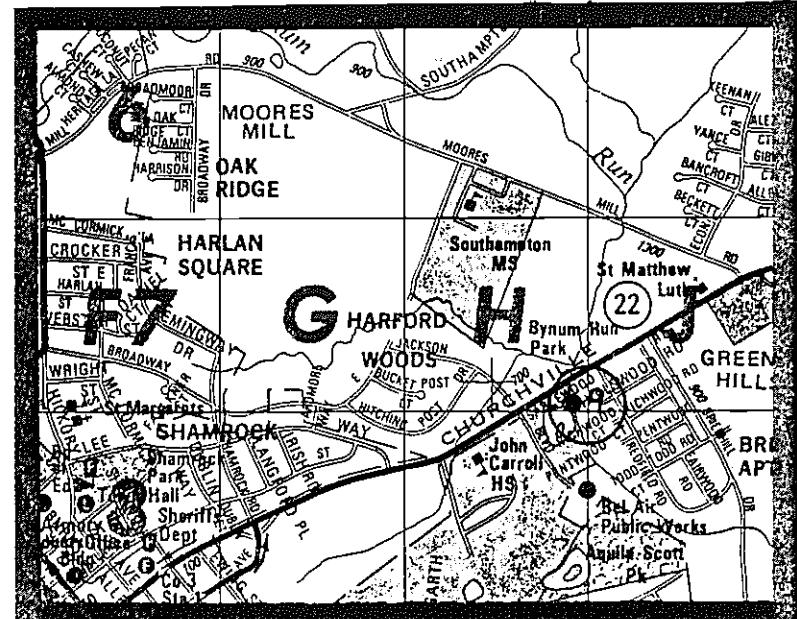


Fig. 9

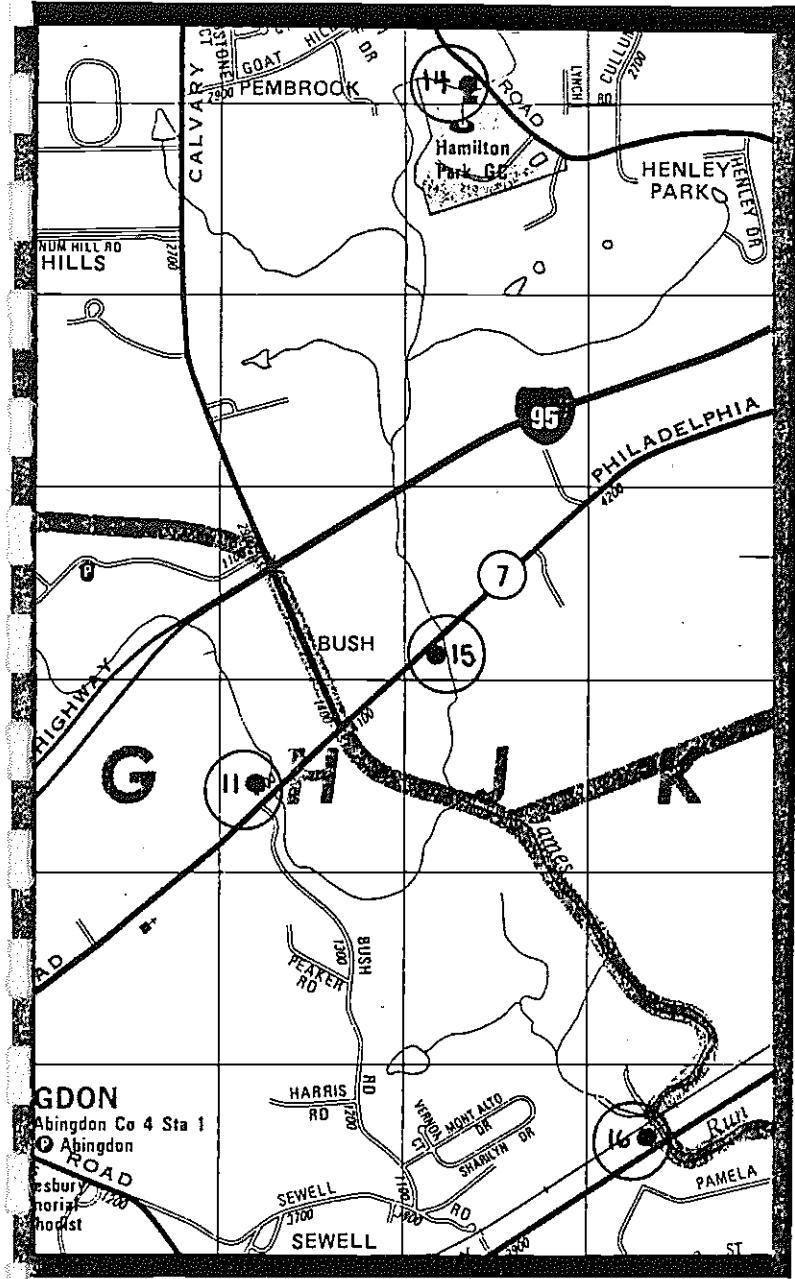


Fig. 10

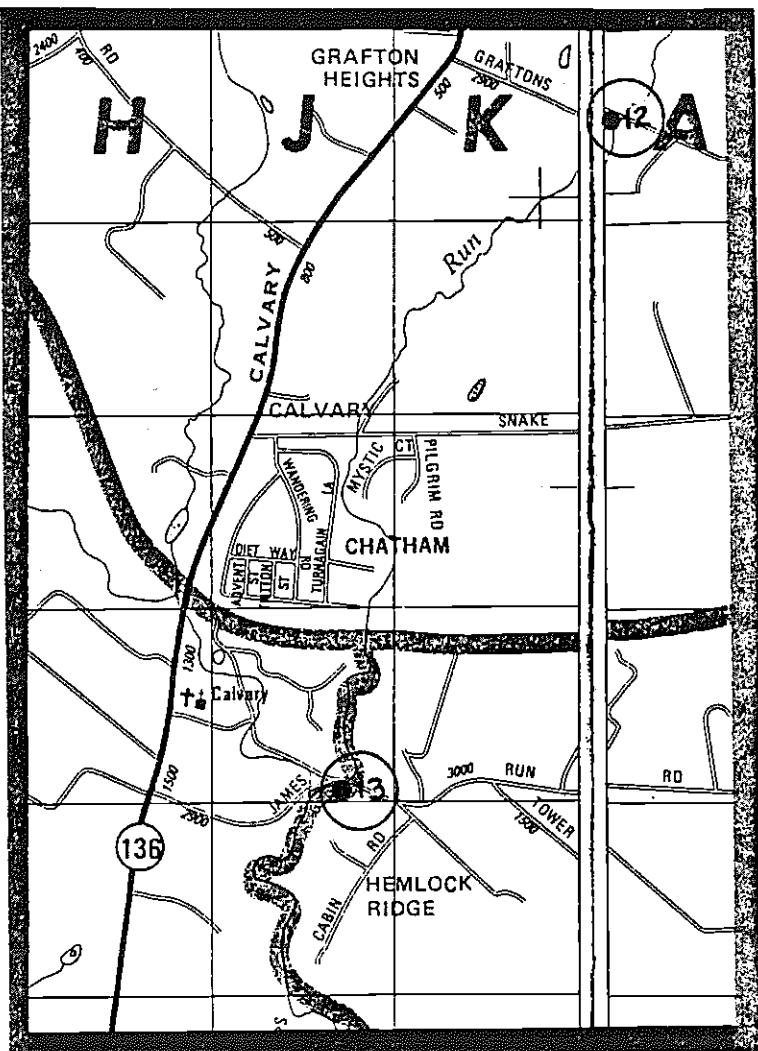


Fig. 11

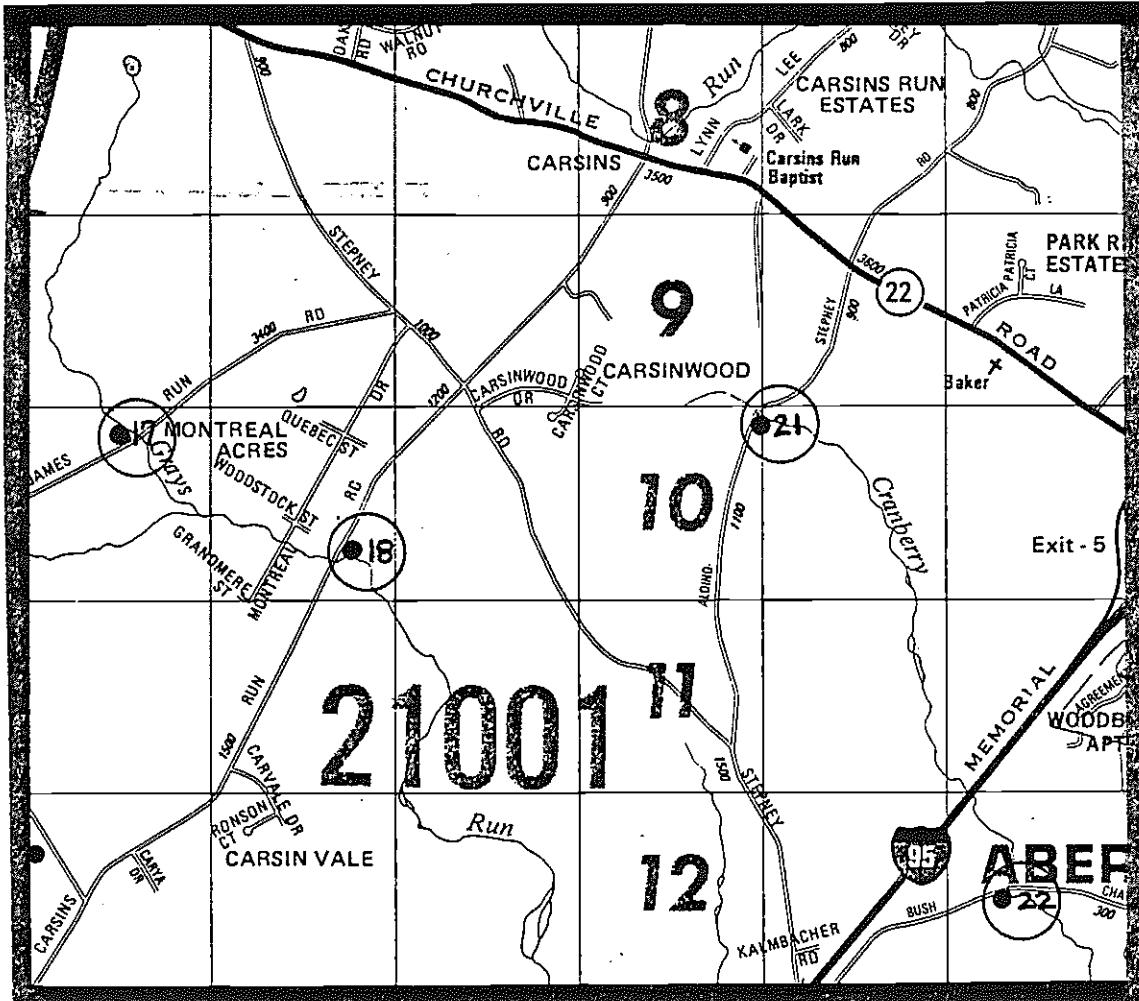


Fig. 12

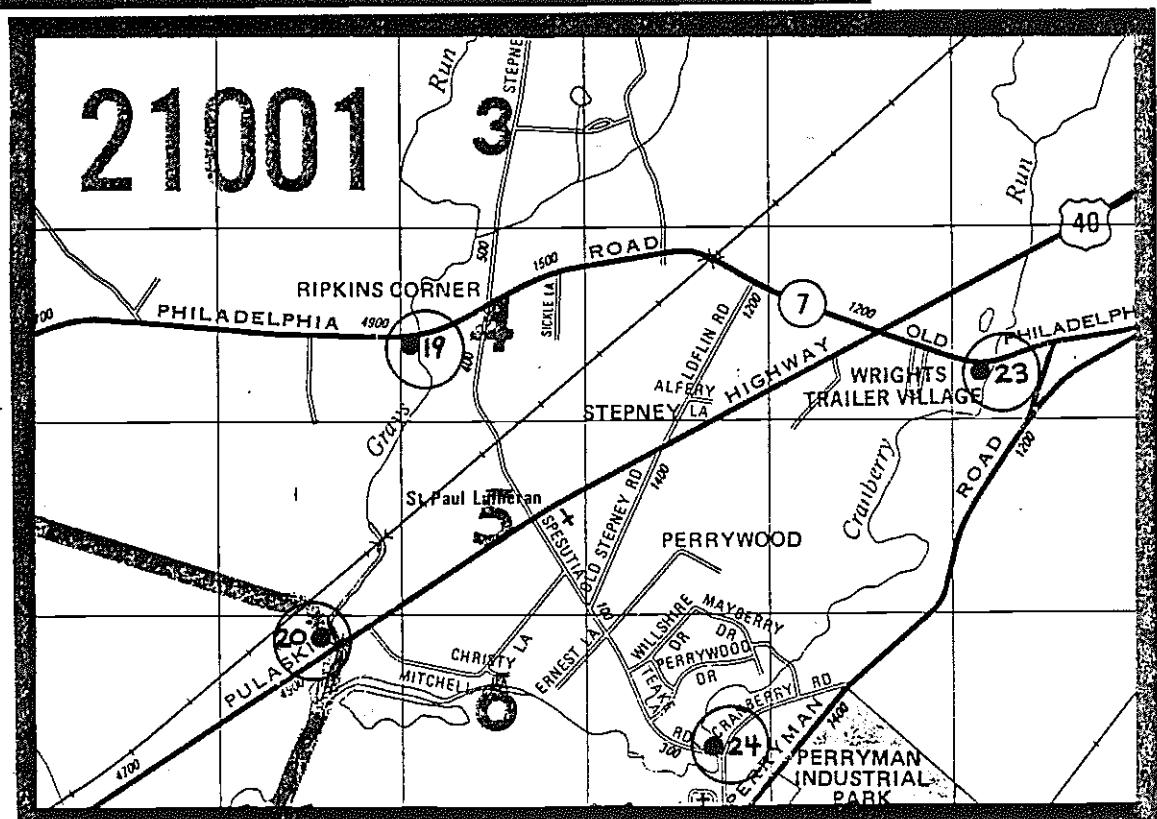


Fig. 13

Materials and Methods

Water samples were collected bi-weekly from 24 sampling stations located in Winters Run, Bynum Run, James Run, Grays Run, and Cranberry Run (see figs. 1-15). All samples were normally collected between 6 am and 10 am and no samples were returned to the lab over 3 hours from the collection time. In an effort to ensure that at least one quarter of our samples were taken during wet weather, we deviated from the bi-weekly schedule from time to time as needed. It was quite difficult to acquire good wet weather data since this year was one of the driest in several decades. Those precipitation events which did occur frequently arose sporadically and did not give us adequate time to mobilize. None-the-less, of the 26 sampling dates, 7 were taken during periods of precipitation or snowmelt.

All samples were treated in accordance with Standard Methods for the Examination of Water and Wastewater (16th ed., 1985). Temperature, dissolved oxygen, and pH were measured "in situ" using a YSI Model 51B oxygen meter and Corning pH105 portable pH meter. Ammonia and nitrate analyses were carried out using an Orion model 407A ionalyzer and corresponding ion specific electrodes. Total phosphate was determined by preliminary persulfate digestion followed by treatment with ascorbic acid for colorimetric comparison. Orthophosphate was determined by the ascorbic

acid technique, omitting the persulfate digestion. Accuracy of all laboratory analyses was assured by constant comparisons with samples of known concentration and by analyses of standard water samples provided by the U.S. EPA. Turbidity was determined using a Jackson candle turbidimeter with a range of 25-1000 Jackson Turbidity Units (JTU). Our lowest limit of actual turbidity detection was thus, 25 JTU. On several occasions, levels of 15 JTU's were estimated. Turbidity units are averages of actual data entered only and do not include days when no turbidity was indicated (values below 15 JTU were not entered). This serves to better illustrate which sites had the worst runoff during rainfall or snowmelt. As a point of reference, 100 JTU is approximately equivalent to 1 gram of soil per liter of water and 0.25 grams of soil per liter will approximate 40 JTU.

For bacteriology, water samples were collected on a biweekly basis from each of the 24 sampling sites. All samples were treated in accordance with section 802 of the Standard Methods for the Examination of Water and Wastewater (16 th edition, 1985). MPN coliform counts were collected at both 24 hour and 48 hour time intervals.

Volume of flow was determined by multiplying the appropriate cross-sectional area of the stream at each sampling station times the rate of flow in mid stream. Since bottom irregularities and flow rate variability from

center to edge of channel introduced some degree of error, these measurements are meant to be comparative only and are not intended to be precise. Flow rates appear to diminish at several downstream localities in the vicinity of Route 7 and Route 40. This is likely due to greater permeability of substrate (and thus, infiltration) and tidal influence at Route 40.

During May of 1988, a biological survey was performed at each sampling site. This survey looked exclusively at larval insect diversity to determine stream health as established by Save Our Streams. This technique uses the presence or absence of three indicator species on 3-4 overturned rocks to evaluate stream health. The rating system works as follows:

Excellent-suited for all human uses (stonefly, mayfly, and caddisfly present)

Good-suited for all human uses except direct consumption (stoneflies absent)

Fair-unfit for most human uses and probably supports few game fish (stoneflies and mayflies absent)

Poor-unfit for all human uses (all categories absent)

To better correlate data with wet weather sampling events, precipitation figures were obtained from Aberdeen Proving Ground (Table 1). Since some precipitation events

that occurred in our area did not occur at APG (Aug. 8 and Sept. 1), those dates are double asterisked.

To ascertain land use patterns above and between sampling sites, the 1986 aerial photographs for Harford County were examined. Land uses on Table 2 were placed in order of approximate total area from largest to smallest. This subjective system has its obvious limitations since we do not quantify land uses. It does however, give the reader a reasonable idea of what is going on between such sampling sites.

May 30	0.00 *	Jan 03	1.50
June 12	0.13	Jan 04	0.80
June 13	0.01 *	Jan 23	0.00 *
June 26	0.14	Feb 04-05	0.23
June 27	0.01*	Feb 06	0.00 *
July 10	0.29	Feb 19-22	0.76 *
July 11	0.00 *	Mar 04-07	0.91 *
July 25	0.00 *	Mar 19	0.00 *
<u>Aug 08</u>	<u>0.00 **</u>	<u>Mar 26</u>	<u>1.59 *</u>
<u>Aug 22</u>	<u>0.50 *</u>	Apr 07-08	0.24
<u>Sept 01</u>	<u>0.00 **</u>	Apr 09	0.00 *
Sept 17	0.43	Apr 15	0.06
Sept 18	0.61	Apr 16	0.00 *
<u>Sept 19</u>	<u>0.03 *</u>	Apr 29	0.05
Oct 03	0.35 *	Apr 30	0.00 *
Oct 17	0.00 *	May 04	0.06
Oct 31	0.00 *	May 05	0.97
Nov 14	0.00 *	May 06	0.61 *
Dec 04	0.03		
Dec 05	0.00 *		
Dec 10	0.21	(Precipitation data courtesy	
Dec 11	0.13	of Wayne Kaiser and Chuck	
Dec 12	0.01 *	Galloway-Aberdeen Proving	
		Ground)	

Table 1-Rainfall data for monitoring dates and several dates previous, if significant. Asterisks indicate monitoring dates, double asterisks indicate significant rainfall not recorded at Aberdeen Proving Ground. Underlined data indicates wet monitoring period.

<u>Site</u>	<u>Upstream land use</u>
1	Wooded-agricultural
2	Wooded-agricultural-residential
3	Agricultural-residential-golf course-landfill
4	Wooded-agricultural-residential
5	Wooded-agricultural-development-Atkisson Res.
6	Agricultural-residential-marsh
7	Horse stables-track
8	Residential-old field
9	Residential-development
10	Heavy development-golf course-residential
11	Wooded-agricultural-development
12	Agricultural-residential
13	Agricultural-quarry-residential
14	Wooded-horse stables-residential
15	Wooded-agricultural-golf course-development
16	Wooded-swampland
17	Wooded-agricultural
18	Wooded-residential-agricultural
19	Wooded-residential-quarry
20	Tidal marsh-wooded-development
21	Agricultural-wooded-residential
22	Wooded
23	Commercial-agricultural-wooded
24	Residential-agricultural-wooded

Table 2-Classification of sites by predominant land uses upstream. Tidal marsh indicates nature of sites along Route 40.

General Results

On table 3, the yearly averages are displayed for each parameter measured at each sampling site. Turbidity was noted at all stations once rainfall or snowmelt was great enough. Values for pH averaged close to neutral or slightly acidic and dissolved oxygen values were generally good except where flow became very sluggish during the summer months.

Nutrient levels are considered to be very high with the exception of Grays Run and the upland areas of Cranberry Run where they are classified as high. Bacterial counts (MPN) are high in all streams and all exceed Class II standards for Maryland Waters.

On the plus side, the biological survey indicated excellent quality at all sites above Route 40 except Bynum Run at Bynum Ridge Road (fair), Bynum Run at Route 22 (good), James Run at Route 7 (fair), Cranberry Run at Old Philadelphia Road (good), and Cranberry Run at Spesutia Road (fair). The presence of large numbers of blackfly at Bynum Run on Route 23 indicate possible fecal contamination (page 43).

What this seems to indicate is that despite high nutrient influx and periodic sediment loads, oxygen levels are still high enough to support a healthy invertebrate fauna. What is also suggested is that these streams are

very close to being pushed beyond their normal capacities to respond to environmental degradation.

11. YEARLY AVERAGES

	SITE #	TEMP. C.	VOLUME JTU*	PH NITRATE-H PHOSPHATE OXYGEN	TOTAL DISSOLVED PHOSPHATE PHOSPHATE OXYGEN	AMMONIA MPH 24HR MPH 48HR % OF SAMPLES INDEX INDEX WITH MPH > 1600								
61	HUNTERS	11.1	29.308	95.4	6.74	2.95	.053	.023	10.22	-0.46	363.0	1037.0	34.6	
62	1	11.5	47.242	26.2	6.76	2.84	-0.64	-.027	10.27	-0.40	354.0	762.0	47.8	
63	2	11.5	64.396	77.7	6.93	2.49	-0.64	-.052	10.10	-0.37	250.0	1261.0	33.3	
64	3	11.6	113.446	111.3	6.74	2.32	-.075	-.036	10.17	-0.34	339.0	989.0	50.0	
65	4	12.2	175.223	103.3	6.76	2.15	-.092	-.057	9.90	-0.45	200.0	811.0	33.3	
66	5	12.9	142.215	94.6	6.81	1.84	-.079	-.038	9.58	-0.42	309.0	947.0	37.5	
67	6	13.6	104.3	6.76	2.26	-.092	-.046	-.048	10.39	-0.44	340.0	1337.0	43.5	
68	BRYNIN	11.5	6.612	75.5	6.70	3.32	-.068	-.032	10.19	-0.47	320.0	960.0	54.2	
69	7	11.7	6.415	78.7	6.98	2.26	-.080	-.024	10.19	-0.40	435.0	1250.0	70.8	
70	8	11.8	31.273	130.6	6.93	2.05	-.067	-.028	10.13	-0.32	249.0	929.0	54.2	
71	9	11.8	42.606	72.2	6.32	1.96	-.086	-.037	9.97	-0.51	221.0	777.0	50.0	
72	10	11.7	54.365	11.9										
73	11	11.9												
74	JAMES	11.3	3.468	56	6.86	1.65	-.100	-.062	9.66	-.070	312.0	666.0	54.2	
75	20	12	11	7.432	66.8	7.29	4.71	-.070	-.028	10.46	-1.48	124.0	885.0	42.1
76	13	11.7	28.681	67	7.34	1.99	-.057	-.024	10.78	-0.48	255.0	782.0	45.8	
77	14	12.1	27.093	120	6.77	2.06	-.097	-.035	10.61	-0.47	263.0	1130.0	62.5	
78	15	12.1	63.436	117	6.74	1.63	-.118	-.040	10.04	-0.60	291.0	810.0	75.0	
79	16	13.4												
80	GRAYS	17	10.8	5.598	82.5	7.04	1.41	-.070	-.034	10.08	-0.82	257.0	921.0	56.5
81	18	10.2	6.229	53.4	6.97	-.83	-.076	-.045	9.38	-0.57	202.0	1132.0	56.3	
82	19	11.5	22.719	71.5	7.01	-.48	-.061	-.019	10.12	-0.47	349.0	1240.0	73.9	
83	20	13.4	44.053	66.2	6.86	.98	-.116	-.031	8.65	-.053	424.0	1522.0	60.9	
84	CRANBERRY	21	10.4	1.603	81.2	6.83	-.91	-.093	-.042	9.61	-0.81	413.0	1196.0	70.8
85	22	11	5.874	76.25	6.99	.95	-.062	-.035	10.67	-0.47	269.0	812.0	60.9	
86	23	11.1	16.553	78.2	6.59	1.97	-.064	-.027	9.62	-126	497.0	650.0	66.7	
87	24	11.8	23.453	74.5	6.65	2.63	-.064	-.032	8.86	-.100	614.0	1556.0	87.5	
88														

Table 3 - Yearly Averages for each Monitoring Site

Specific Results

pH

Values for pH in streams will fluctuate due to biological activity, precipitation, and geological substrate. Waters with pH values of 6.5 to 8.5 meet Maryland Standards for all classes of waters. As can be noted by comparing the values on Table 3 to the daily graphs (pages 90-91), while average values meet water quality standards daily fluctuations are frequently below 6.5. Some of the lowest pH values corresponded with periods of precipitation and the lowest measured value was site 24 in Cranberry Run on March 26, 1988. This value of 4.5 occurred during very heavy rainfall and the pH value of the rain was 3.8 on that day. Other rain pH values were 3.5 for January (1/8) snow, 4.2 on April 9, and 4.4 on May 6, 1988. Stream pH values do not always follow precipitation because of buffering, dilution, and the other aforementioned factors. The low reading at site 24 on 3/26/88 was very unusual .

Over the year of monitoring, pH values either remain fairly consistent or decline slightly depending on the stream and sampling site. Cranberry Run, site 22 and Grays Run, site 17, for example, show rather obvious downward trends in pH, from about 7.3 to 6.8. While this could very likely be due to increased precipitation during the winter

and spring months compared to the previous summer and fall, we can only speculate at this time.

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature usually display inverse relationships since as water temperature rises, its ability to hold oxygen diminishes. For recreational waters, dissolved oxygen should not drop below 5 mg/l. Natural trout streams must not drop below 6 mg/l and must also maintain temperatures of 68 degrees Farenheit or below.

All streams rose above 68 degrees Farenheit (20 degrees Celsius) during July and August. James Run maintained the coolest temperature during the summer months and Cranberry Run at Aldino-Stepney Road had only one date above 20 degrees Celsius, on August 22 (see pp. 58-69).

Dissolved oxygen readings (pp. 80-85) were affected by both water temperature and streamflow since low flow translates to little mixing or oxygenation. Although for the most part the streams are well aerated, oxygen levels dropped to below 5 mg/l at sites 17, 18, and 20 (Grays Run) and sites 21 and 24 (Cranberry Run) during July, August, and early September when combinations of low flow and warm temperatures prevailed. It is possible that algal photosynthesis had some effect on keeping oxygen levels higher than one might expect as waters warmed to levels

above 20 degrees Celsius. Since we did not monitor cholorphyll a concentrations, extrapolation is not possible.

Turbidity

Turbidity, expressed in Jackson Turbidity Units (JTU's), is actually a measurement of sediment loading in this study, since algal growth that occurs in these streams is below what we can measure in JTU's. As previously indicated, the averages on pages 182-184 are compiled only from readings obtained during rainfall and do not include levels below 15 JTU's.

What is important to note (pp. 185-196) is that whenever significant rainfall events did occur, turbidity levels were measurable at virtually all sampling points. Those sites demonstrating the greatest average turbidity (over 100 JTU) during rainfall were Winters Run at Ring Factory Rd. and Winters Run Rd. (sites 4&5), Bynum Run at Route 23 and Wheel Rd. (sites 7&10), and the lower end of James Run (sites 15&16). Those sites demonstrating levels over 150 JTU (State standard limit for all waters) at some point during the year were Winters Run (sites 1,4,&5), Bynum Run (sites 7&10), and James Run (sites 15&16). The worst site was Bynum Run (site 10) on March 5, 1988 with over 400 JTU. This site is directly downstream from development taking place along Route 22 and McPhail Rd.

As can be noted, Grays Run, Cranberry Run, and the upper reaches of James Run had the lowest turbidity readings. In general, these sites correspond to areas of lowest development levels and they tend to be wooded or used as pastureland.

Nutrients

Nutrients are of great concern because they increase the biological productivity of any body of water thereby leading to algal blooms which diminish water clarity. In some situations, toxins can be produced by these algae which then cause fish kills. More commonly the algae, because they have a short life span, die and are subject to decomposing bacteria which deplete oxygen levels. This condition also causes fish kills and leads to poor water quality. Nutrients generated by human and animal waste are usually accompanied by high coliform bacteria counts whereas nutrients that are of chemical origin (fertilizers, phosphate detergents, etc.) are not accompanied by higher coliform counts. One caveat to this generalization might be when groundwater loading of nitrates from septic systems allows for sufficient retention of effluent so as to see no coliform bacteria present. We measured nitrate (the most commonly noted nitrogen species), ammonia (found at high levels where nitrogenous pollutants are fairly close by),

total phosphate and ortho phosphate (the most biologically available form). Nutrient data are found on pages 103-165.

For nitrates, the upper reaches of Cranberry Run (sites 21&22) and the lower reaches of Grays Run demonstrated the lowest averages, but were still high at 0.48 to 0.98 mg/l. Between sites 21&22 exists the most completely wooded watershed area noted in this study. According to Neilson's (1981) rating, levels of total nitrogen (we monitored only nitrate and ammonia) should ideally be below 0.1 mg/l for all uses and preferably below 0.01 mg/l. Levels above 1.0-3.2 mg/l are considered to be only marginally acceptable for use as public drinking water.

Since nitrates are soluble in water, they are transported easily into groundwater and by overland flow. Rainfall also contains nitrates and we detected values of from 0.52 to 0.56 mg/l in our rainfall samples (p. 36). These concentrations are due largely to acidification by nitrous oxides (from automobile exhausts and industrial emissions) and secondarily by atmospheric nitrogen fixation. Nitrogen of atmospheric origin is usually absorbed by vegetation unless runoff carries it directly to receiving waters or if no vegetation is present.

Although nitrate levels appear to fluctuate with no apparent correlation with rainfall, several sites on Cranberry Run (sites 23&24) show higher levels in May, 1987 dampening to lower levels in 1988. James Run site 13 shows

a very severe problem in 1987 with nitrate levels rising to over 23 mg/l on July 25 (p. 112). The next site downstream also showed high levels, dampening with time, though with a considerable degree of dilution. Since so high a reading could be considered to be due to sample testing error, a scan of ammonia also reveals a very high spike to 1.5 mg/l (p.128). Since coliform levels for that date do not demonstrate unreasonably high levels, both manure and direct discharge of human waste can be ruled out as sources of contamination. Since site 12 showed no such high reading, the sleuth is left with the conclusion that something either leached from or was dumped between the two areas. The residential area of Chatham, the Genstar Quarry, and agricultural land separate the two sites. A later reading on July 15, 1988, also yielded a high value (4.7 mg/l).

In general, nitrate levels are significantly elevated above former studies that have been done. This will be covered in greater detail under discussion.

Nitrate levels are generally higher upstream than downstream except right near source areas as demonstrated by Bynum and James Runs. This is a normal result of biological activity. Grays Run shows a slight increase as it flows into Church Creek Marsh and Cranberry Run completely reverses the trend demonstrating highest levels at Spesutia Rd. (site 24) where it slows to become part of a beaver pond. Most human impacts and therefore the highest readings

are found at the last 2 sites (see Table 2 and pp. 116-117). Average ammonia levels are very high in the lower section of Cranberry Run (sites 23&24), and it must be stated that most of the higher inputs were associated with large pulses that were not necessarily associated with rainfall. March 26, 1988, was an exception to that when 1.2 inches of rainfall drove ammonia, phosphate, and turbidity levels higher than normal. The presence of ammonia is an indicator of nearby fecal or other biological decay and its presence at sites 23 and 24 could be due to nearby dwellings or businesses with faulty septic systems. There is also considerable farming activity flanking the stream in this area. Both sites are located downcurrent of Route 40. Site 21 (p.132) monitors water that has flowed through areas of mixed land use including low density residential, small farms, and pastures. Ammonia levels there could be due to runoff from pasture areas.

Although not as high as those readings taken at the lower Cranberry Run sites, ammonia levels showed similar spikes at all other sites throughout the year. Some of these spikes may be due to the periodic decay of algae or some other natural phenomena. When active decay is occurring in streams, one should see a concurrent drop in oxygen levels. Although this does happen on some occasions, high ammonia levels are most frequently associated with high

rainfall a day or two prior to the monitoring day, indicating that runoff is the key problem.

Total phosphate levels (pp. 135-137) averaged between 0.05 and 0.10 mg/l in most streams. Again using Neilson's rating scheme, these levels are considered to be indicative of eutrophic conditions and are marginally acceptable for aquatic life. Spikes of phosphorus almost always occur during or after periods of heavy runoff. This is to be expected since phosphates are bound to sediment particles and are carried into streams when soils are eroded during downpours or to a lesser extent by snowmelt. Several phosphorus spikes manifested themselves when no runoff had occurred or was occurring. Possible reasons include direct discharges of cleaning agents or sewage into streams, atmospheric deposition, animal wastes from barn yards (see table 4, Mahantanyo Watershed), direct dumping, cattle feeding in streams, or sediment violations.

Phosphate levels for one rainfall measured 0.052 mg/l for total and 0.004 mg/l for ortho phosphate. Although one rain sample yielded 0.91 mg/l for total phosphates and 0.29 mg/l for ortho phosphates (see table 5), we believe this to be an error in sampling (the collecting beaker was probably not acid washed).

Thus for all nutrients, levels in streams are high. While input from precipitation can account for a percentage of these nutrients, other studies (Swank and Douglass, 1977)

indicate that vegetation, when active metabolically, should be able to use and therefore dilute them. High levels are caused by both agriculture and residential inputs. While agricultural inputs are greatest on Winters Run, residential and development influences dominate Bynum Run and lower Cranberry Run.

Bacteriology

In general, all streams surveyed had high MPN counts. Of the six, four streams had two or less impulse counts in excess of 1000 coliforms/100 ml. Average counts for all streams are summarized on Table 3. Counts (48 hour) from individual streams are as summarized below.

Winters Run MPN counts ranged from 80 to >1600 coliforms per 100 ml of sample. Sampling sites 1 and 3 had MPN counts constantly higher than 1000. The remainder of the sampling sites had MPN counts which averaged less than 1000.

Bynum Run MPN counts ranged from 130 to >1600 coliforms per 100 ml of sample. Sampling sites 7 and 9 had MPN counts of 1337 and 1250 respectively. The remainder of the sampling sites had MPN counts which averaged less than 1000.

James Run MPN counts ranged from 80 to >1600 coliforms per 100 ml of sample. Sampling site 15 had MPN counts constantly higher than 1000. The remainder of the sampling sites had MPN counts which averaged less than 1000.

Grays Run MPN counts ranged from 140 to >1600 coliforms per 100 ml of sample. Sampling sites 18, 19 and 20 had MPN counts of 1132, 1240, and 1522 respectively. The remainder of the sampling sites had MPN counts which averaged less than 1000.

Cranberry Run MPN counts ranged from 130 to >1600 coliforms per 100 ml of sample. Sampling sites 21 and 24 had MPN counts of 1196 and 1556 respectively. The remainder of the sampling sites had MPN counts which averaged less than 1000.

All of the sampling sites had MPN counts which are considered to be high. Reviews of other studies of the Bush River Drainage Basin indicate that the counts documented in this report are consistant with those previously derived. The probable sources for these counts would appear to be septic system input and runoff from agricultural land.

Previous studies have concentrated on the area of the Bush River below the railroad bridge and the relationship of that area to the interceptor lines feeding the Sod Run Plant. The current study would indicate that sources of

bacterial contamination are present for each of the tributaries identified and that at least one of the streams is receiving bacterial sources that it cannot reduce by normal events.

Specifically, Grays Run appears to be receiving a source of microbial contamination between sites 17 and 18 (pp. 178-179) which continues to be measurable along the remainder of the stream, possibly masking out other sources of contamination further downstream.

The other tributaries, Winters Run, Bynum Run, James Run, and Cranberry Run have impulse points of higher than expected MPN counts. However, each tributary appears to be able to reduce the bacterial population by the next sampling site.

Discussion

The purpose of this study is to define the health of these streams, the impact of Harford Countians upon them, and the effects of those streams on Bush River and the Chesapeake Bay.

With respect to water temperature, the only problem is that streams rise above 68 degrees Farenheit (20 degrees Celsius) during the months of July and August. This is a problem, not only for fish such as trout. As water warms up, its ability to hold oxygen diminishes and all healthy aquatic life begins to feel stress. Trout are good

indicator species since they are stressed at 68 degrees Farenheit and die at 72 degrees Farenheit. They also dine on invertebrates which require high oxygen levels. Their disappearance from a body of moving water is a reliable sign that oxygen levels are dropping.

One solution, where feasible, is to revegetate stream banks with arborescent vegetation. This will not only shade water, keeping it cooler, but tree canopies dissipate the energy of raindrops and their roots hold soil and slow erosion. Bay and State foresters can assist citizens in the development of planting designs and plans.

Warm temperatures are not the only factor that can drop oxygen levels. Too much organic matter can allow for high bacterial counts which will deplete water column oxygen. Such was probably the case on August 6 at site 17 (p. 82) and on July 11 at site 20 (p. 83) when MPN's were high and oxygen was at its lowest point. Nutrient levels dropped slightly on these days which would be consistent since bacteria consuming organic matter will utilize nitrates and phosphates as well. High organic loading is one reason that low oxygen levels and higher temperatures do not always correspond.

Although all streams have lower oxygen readings during the warmer months, our findings indicate that the lower sections of Grays Run and Cranberry Run have the most serious problems with low oxygen and that it is probably due

to organic loading. These same areas showed high ammonia levels indicating a relatively fresh pollution source.

With respect to turbidity, the sites which demonstrate the highest sediment loading were Bynum Run at Route 23 and at Wheel Rd. Above Route 23 is a horse stable and practice track and above Wheel Rd. considerable amounts of development are taking place, especially at Upper Crest, Greenbriar Hills, and Glenwood Garth. On Winters Run, levels were high at the Ring Factory Rd. and Winters Run Rd. sites. Inputs between Route 1 and Ring Factory Rd. are largely agricultural and at Winters Run Rd. the water has passed through Atkisson Reservoir where we would expect settling and nutrient absorption to occur. Higher levels at Winters Run Rd. (Singer Rd.) indicate sediment input either from agriculture or development, both of which take place near there. James Run at Route 7 and Route 40 showed high turbidity levels while they were slightly lower at Route 543. Sediment was likely coming from agricultural fields or from new bridge construction taking place in the vicinity.

Nutrients of both nitrogen and phosphorus are higher than they should be in all streams but nitrates show significant increases from historical data. While EPA data from 1967 (DNR, 1976) showed a total nitrogen measurement of from 0.1 to 1.0 mg/l for the Bush River, a 1973 Water Resources Administration Study found nitrate-N levels of 1.36 mg/l in James Run (WRA, 1975). The U.S. Army sampling

of Winters Run in 1963-1964 (DNR, 1976) showed nitrate-N levels ranging from 0.66 to 1.5 mg/l. Our average readings for James Run range from 1.63 to 4.71 mg/l and from 1.84 to 2.95 mg/l for Winters Run. Bynum Run averages ranged from 1.96 to 3.32 mg/l and the high in Grays Run was 1.41 mg/l, while 2.63 mg/l was the worst average in Cranberry Run. Ammonia levels reached their highest averages in Cranberry Run below Route 40, at site 13 in James Run, and at the head of Grays Run (site 17).

While nitrogenous pollutants have increased over the past decade, phosphorus readings, though still considered high, may be somewhat comparable to historical data. While again emphasizing that past data are sketchy, EPA readings of 1967 show total phosphorus in the Bush River to read between 0.025 to 0.1 mg/l with a spike to 0.25 mg/l. The WRA study of 1973 found total phosphorus of 0.15 and ortho phosphorus readings of 0.05 mg/l. Our readings are somewhat comparable to these with the exceptions that many of the spikes which we have recorded go to as high as 0.8 mg/l. Thus, while averages may appear similar to past readings, levels occurring during periods of runoff may be higher. Assumptions here are difficult since past data do not include sampling distributions which include wet weather, and because we do not know the true duration of the spikes since we monitored only biweekly.

What may be more valuable is to compare our information with data derived from other studies in the eastern United States. Table 4 lists the name of the watershed or study along with the type of watershed and nutrient readings obtained.

<u>Study & Watershed Type</u>	<u>NO₃-N</u>	<u>NH₄-N</u>	<u>T.PO₄-P</u>	<u>O.PO₄-P</u>
<u>Burton et.al. Florida</u>				
Forested-agricultural	0.046 (.053)	0.044 (.042)	0.329 (.405)	0.092 (.121)
Suburban	0.306 (.269)	0.082 (.072)	2.46 (1.21)	0.047 (.035)
Urban	0.076 (.093)	0.070 (.108)	3.08 (1.77)	0.078 (.096)
<u>Swank & Douglass</u>				
<u>NC - Ceweeta River</u>				
Precipitation	.002-.006	.002-.005	.001-.002	-
Mature hardwood-stream	.128-.150	.072-.133	.003-.006	-
<u>Overcash et.al.</u>				
<u>Chowan River - NC & VA</u>				
Agricultural piedmont	.00-.17 (.11)	.00-.17 (.01)	.02-.5 (.11)	.05-.21 (.11)
Poorly drained coastal plain	.00-7.69 (.48)	.00-1.3 (.17)	.01-1.53 (.21)	.03-1.65 (.19)
Well drained coastal plain	.00-8.96 (.07)	.00-1.3 (.07)	.02-.60 (.07)	.00-.59 (.1)
<u>Heald & Gourek</u>				
<u>Mahanantango Watershed, PA</u>				
Below big farm-pre storm	-	-	-	2.36
During storm	-	-	-	2.90
After storm	-	-	-	1.22
Above farm-pre storm	-	-	-	.0007
During storm	-	-	-	.0017
Post storm	-	-	-	.0033
<u>Likens et.al.</u>				
<u>Hubbard Brook, NY</u>				
Forested	0-4.0	-	-	-
Devegetated	.5-80	-	-	-
<u>Martin & Clayton</u>				
<u>Jones Falls-Baltimore, MD</u>				
Urban	11.3-16.9 (13.6)	0.9-2.2 (1.1)	.42-4.12 (1.08)	.14-.66 (0.26)

Table 4-Nutrient readings from several watershed studies. Figures in parentheses represent arithmetic means. All readings are in mg/l.

It becomes immediately obvious that nitrate-N levels in our streams are 1000 times greater than those readings taken from forested ecosystems in northern Florida (Burton, et.al.) or North Carolina (Swank and Douglass) and are 10 times higher than a suburban Florida watershed. While the Chowan River study showed several high spikes, the arithmetic means were substantially lower than those in our study.

Ammonia levels are roughly twice the levels found in northern Florida or the Ceweeta River, but comparable to levels noted in the Chowan River.

What is very interesting is that the phosphate levels, both ortho and total, found in our streams were substantially lower than readings noted in either Florida or the Chowan River. They were, however, an order of magnitude higher than those noted in the forested Ceweeta River Watershed (Swank and Douglass, 1977). This could be due to several factors:

- 1) Our dry weather resulted in significantly less runoff than might otherwise have been observed.
- 2) The phosphate ban in Maryland is doing some good.
- 3) The significantly higher rainfall one would expect in Florida, coupled with their agricultural techniques has resulted in higher phosphorus loading there.

The Swank and Douglass study offers the best comparison with a completely undisturbed forested system. As can be noted on Table 4, fewer nutrients left the system than entered it via rainfall, due to uptake by vegetation. Similar findings were expressed in the Hubbard Brook study (Likens et.al.). In our case, approximately five times the nitrates found in our rainfall (see Table 5) are found in our streams, while phosphate levels are roughly equivalent. Ammonia levels drop or remain similar.

	<u>pH</u>	<u>NO₃-N</u>	<u>NH₄-N</u>	<u>T.PO₄-P</u>	<u>O.PO₄-P</u>
6-22-88	-	0.62	0.091	0.29*	0.09*
7-21-88	4.4	0.56	0.195	0.052	0.004

Table 5-Rainfall data for pH and nutrients taken on two days. Rain was collected at Harford Community College. Readings are in mg/l. * indicates possible contamination.

A comparison with the Jones Falls data (Table 4) indicates that although Harford County streams are very high in nutrients, they do not yet compare to the exceedingly high levels noted in urban runoff. This should not be taken as cause for rejoicing; nutrient levels in our streams are 10 to 100 times higher than they should be to maintain high water quality and to have minimum impact upon Bush River and Chesapeake Bay.

A comparison with our own Bush River data collected on July 15, 1988 and Harford County DPW (Ludwig, 1987) information indicate that nutrient loading from all sources is contributing to degraded water quality in the Bush River. While the DPW report found total nitrogen levels to be between 1.0 and 7.5 mg/l we noted nitrate levels 1.05 and 4.05 mg/l. The DPW total phosphorus average of 0.3 mg/l was considerably above levels found in the feeder streams (see table 3). Since the DPW lower limit of detection was 1 mg/l for ammonia, our values are more accurate, but are all below their limit of detection. Our highest ammonia readings (0.95-1.0 mg/l) were taken in the vicinity of the Sod Run outfall.

Thus it can be stated that although the streams of this study make substantial nutrient contributions to the Bush River, there are rather high concentrations entering from around the shoreline of the river itself. One would expect that such high nutrient loading would result in very high algal concentrations in the river and that is exactly what we see. Although the actual chlorophyll a concentrations will not be evaluated at the time of this writing, a visual analysis yielded that secchi disk visibility in the upper reaches of the river was about 1 ft. (a very poor reading) and that the water was deep green in color.

The combination of nutrient inputs resulting from stream loading and shoreline impacts are resulting in very

high turbidity due to algal growth. Sediment erosion, transport, and deposition in the Basin during storm events raises phosphate levels, and introduces finer clays which are easily resuspended during windy periods.

Conclusion and Recommendations

In all streams in the Bush River Watershed, nutrient levels, bacterial counts, and sediment loading have been found to be excessive. Because nitrogenous nutrients are always high it is plausible that groundwater or surface contamination has occurred in many areas. If well reading data from the County Health Department do not yield higher nitrate levels, then contamination is due to surface impacts such as animal waste, direct septic tank input, or runoff from lawns, agricultural fields, or roads.

The fact that sites studied here have larval insect populations that are considered to be healthy indicates that nutrients, sediment, and bacteria have not yet completely overwhelmed the streams. It is likely that if current trends continue that we will begin to see serious degradation. Several sites, specifically 8, 15, and 24 are already seriously compromised.

General recommendations for all areas are as follows:

- 1) In areas of construction, continue to maintain strict adherence to sediment control regulations. Large,

exposed tracts create the most severe problems and have not adequately held soil movement in check.

2) On agricultural land, encourage the utilization of best management practices (BMP's). Setbacks from streams of all sizes, winter cover crops, and grassed filter strips and swales are several examples of practices which will help. Proper manure management is very important and spring developments will keep livestock out of streams.

3) Encourage the planting of arborescent vegetation along streams whenever possible.

Specific recommendations for each stream are:

Winters Run-High bacterial counts at Route 1 indicate the need for septic tank evaluation and manure management. Better sediment control needs to be addressed below Route 1, and above Route 40.

Bynum Run-High ammonia and nitrate levels and low oxygen at Bynum Ridge Rd. indicate septic effluent leakage into stream from surrounding development and/or stables above Route 23. Very high turbidity below areas of development needs to be very seriously addressed.

James Run-One of the more serious nitrogen problems exists above James Run Rd. This needs to be further

investigated. Runoff due to agriculture and construction should be addressed above Route 7.

Grays Run-Bacteria levels increase as one moves downstream. Older residences with inadequate septic systems are likely the problem.

Cranberry Run-Serious nitrogen problems below Route 40 need to be addressed.

Acknowledgements

We would like to thank Deborah Wrobel, Lisa Jacobson, and Anita Pastelak for their excellent laboratory work. Michael Dombroskie and Donna Pearce deserve our most sincere thanks for braving the elements to obtain water samples every two weeks without fail. Lisa Berry deserves credit for her excellent typing and computer work.

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APPENDICES

Site	Stonefly	Mayfly	Caddisfly	¹ Blackfly	Rating
1. Winters Run-Pleasantville Rd.	4	5	5	1	Excellent
2. Winters Run-Carrs Mill Rd.	1	2	6		Excellent
3. Winters Run-Bel Air Rd.	5	6	7		Excellent
4. Winters Run-Ring Factory Rd.	1	1	1		Excellent
5. Winters Run-Singer Rd.	2	2	2		Excellent
7. Bynum Run-Route 23	21	-	-	27	Excellent
8. Bynum Run-Bynum Ridge Rd.	-	-	7		Fair
9. Bynum Run-Route 22	-	5	-	3	Good
10. Bynum Run-Wheel Rd.	1	3	-	1	Excellent
11. Bynum Run-Route 7	1	2	2		Excellent
12. James Run-Graftons Lane	1	2	5	4	Excellent
13. James Run-James Run Rd.	5	3	3		Excellent
14. James Run-Route 543	1	1	6		Excellent
15. James Run-Route 7	-	-	3		Fair
17. Greys Run-James Run Rd.	1	7	12		Excellent
18. Greys Run-Carsins Run Rd.	1	2	13		Excellent
19. Greys Run-Route 7	12	1	4	2	Excellent
21. Cranberry Run-Aldino-Stoney Rd.	2	-	8		Excellent
22. Cranberry Run-Bush Chapel Rd.	4	24	7		Excellent
23. Cranberry Run-Route 7	-	6	4	1	Good
24. Cranberry Run-Soesutia Rd.	-	-	30		Fair

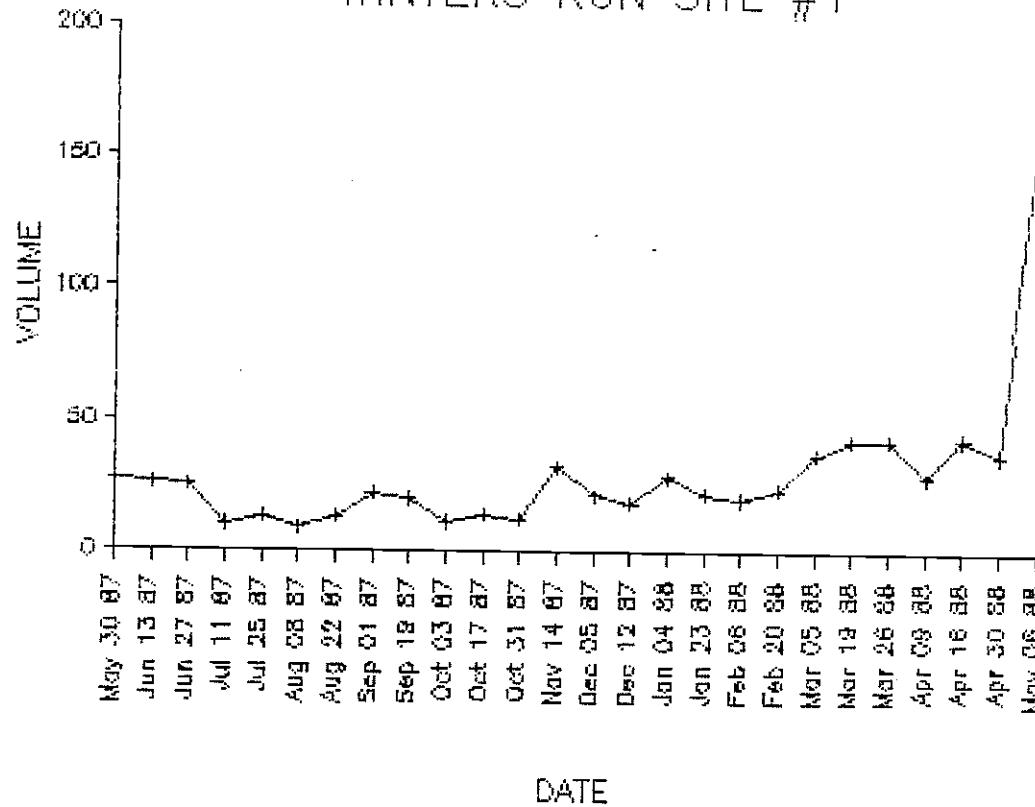
¹ Blackfly larvae, although are not one of the main three indicator insects used in the rating, they indicate possible fecal matter effluent.

2 In cases where only Stoneflies were found on the three sample stones, after looking further, Mayflies and Caddisflies were usually found.

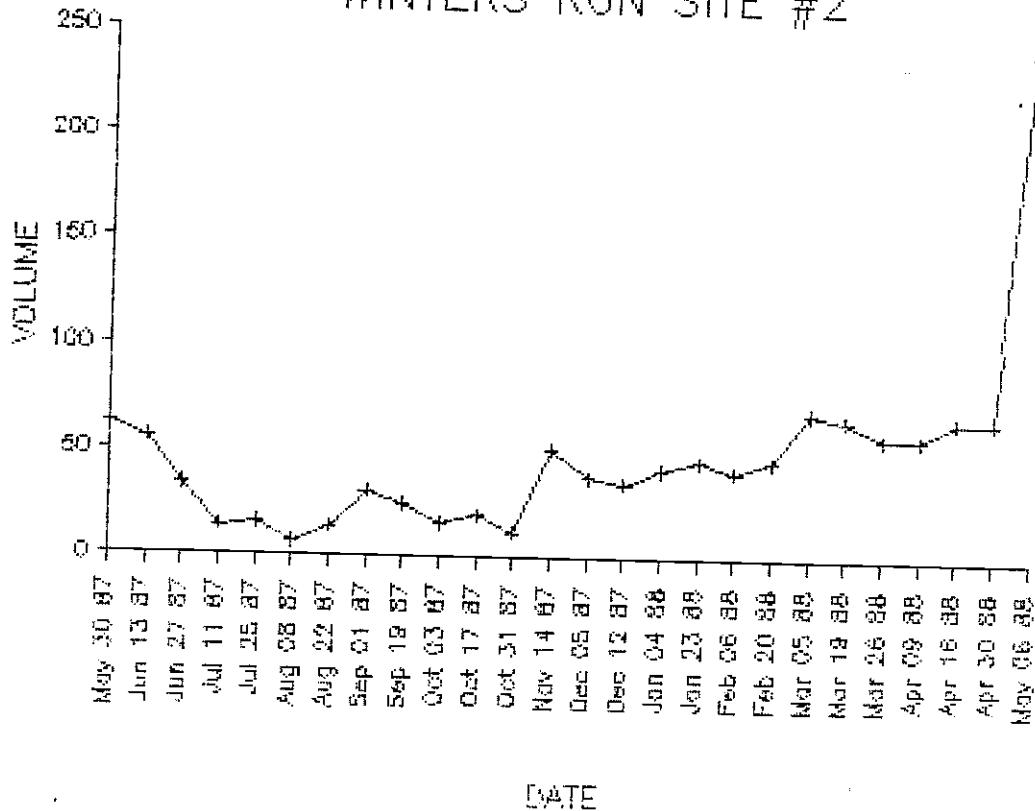
Table 6-Results of insect larval sampling study .

(Cubic Volume
feet/second)

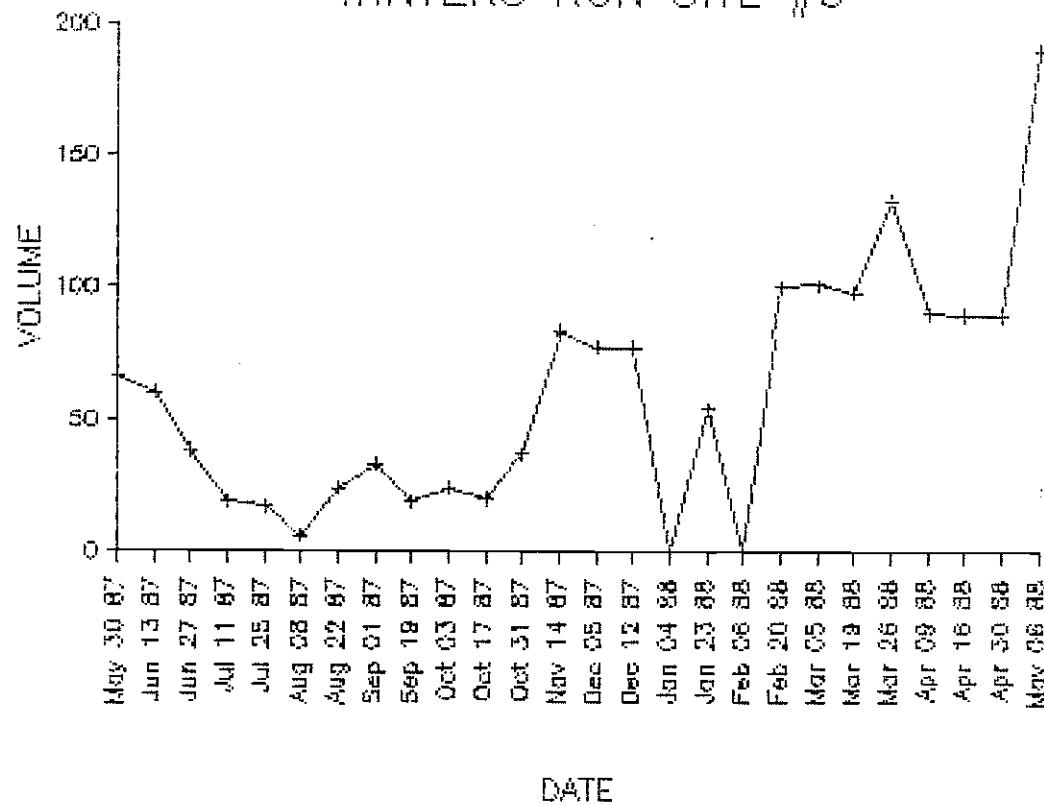
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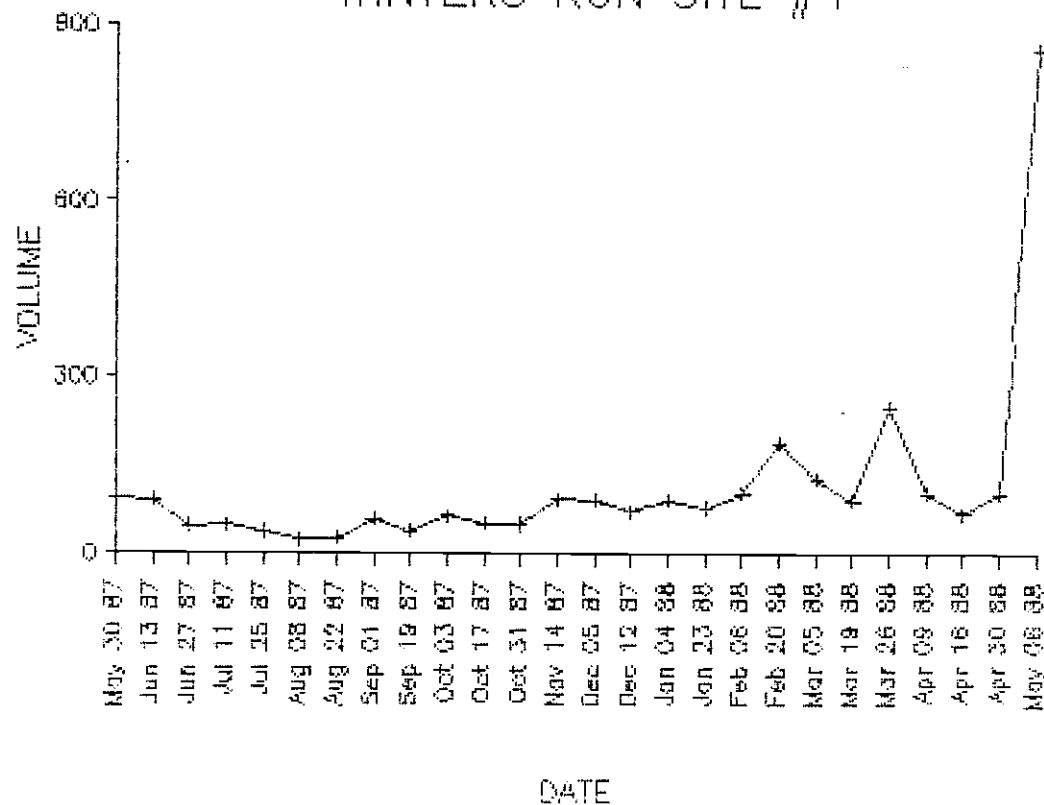
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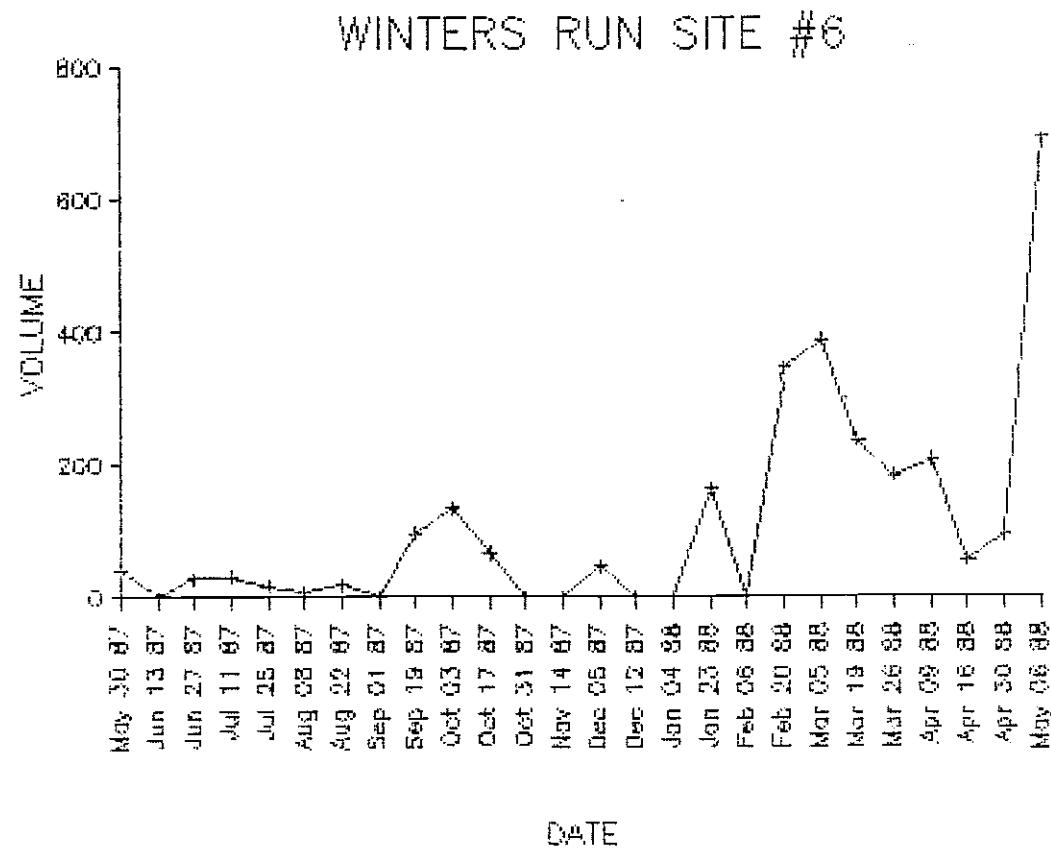
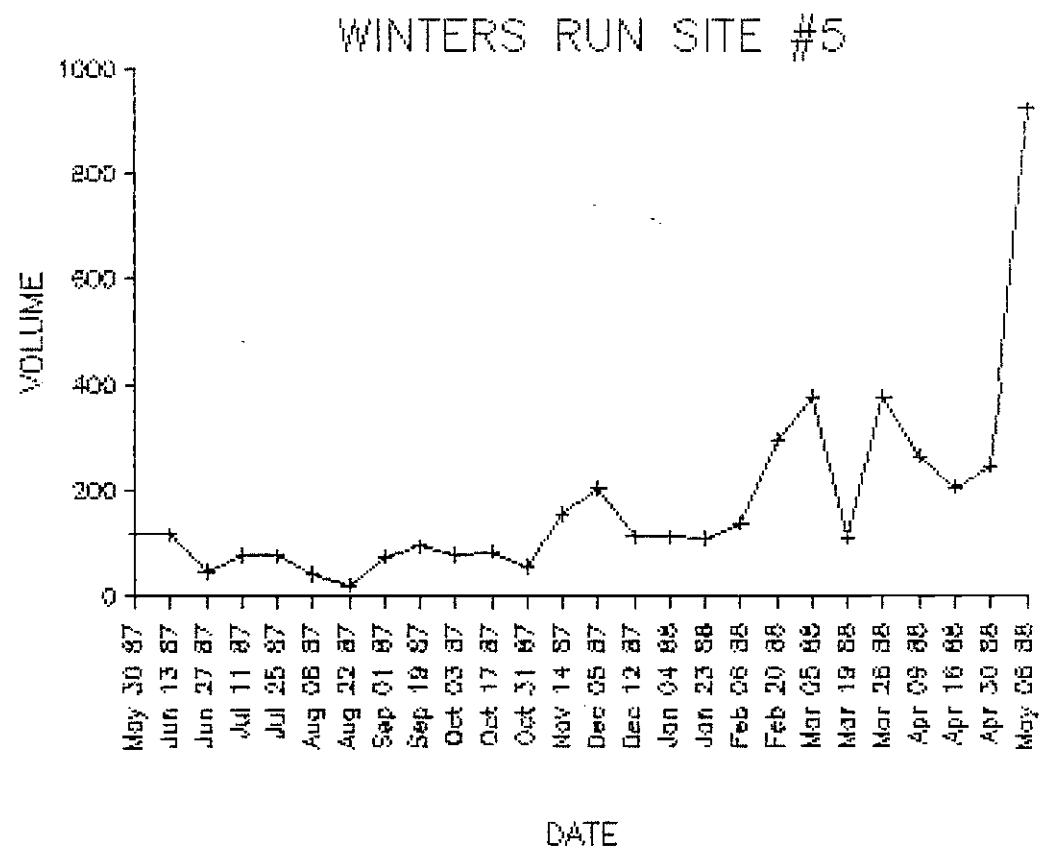


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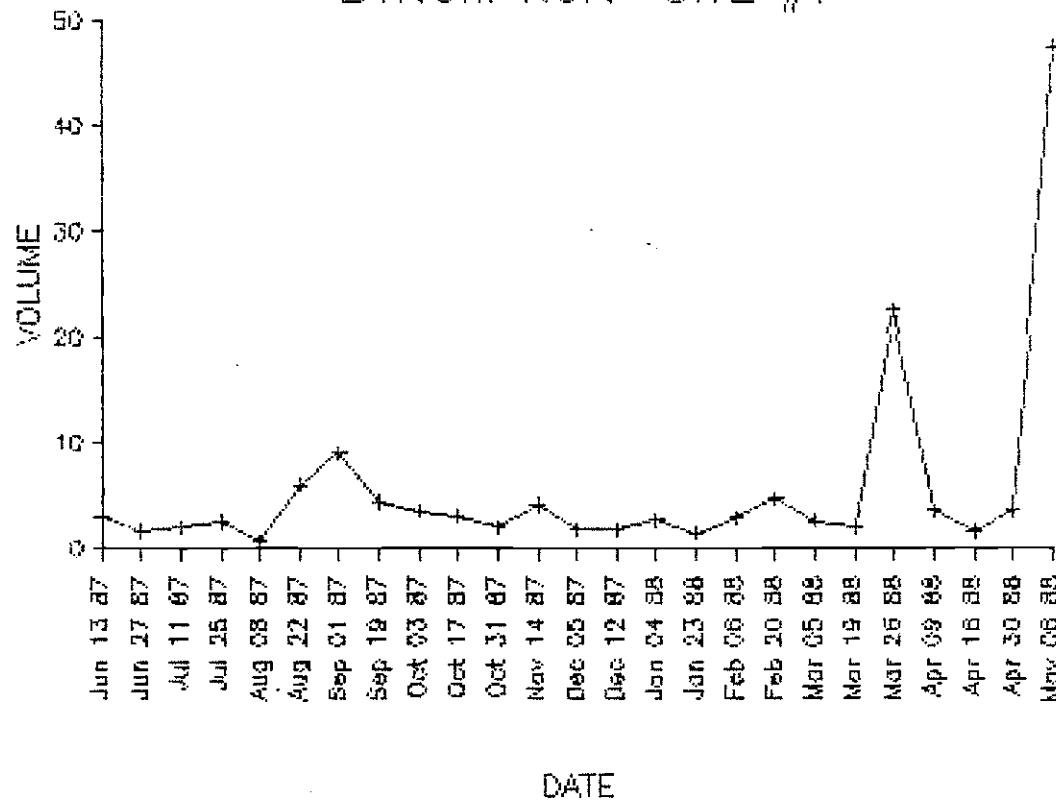


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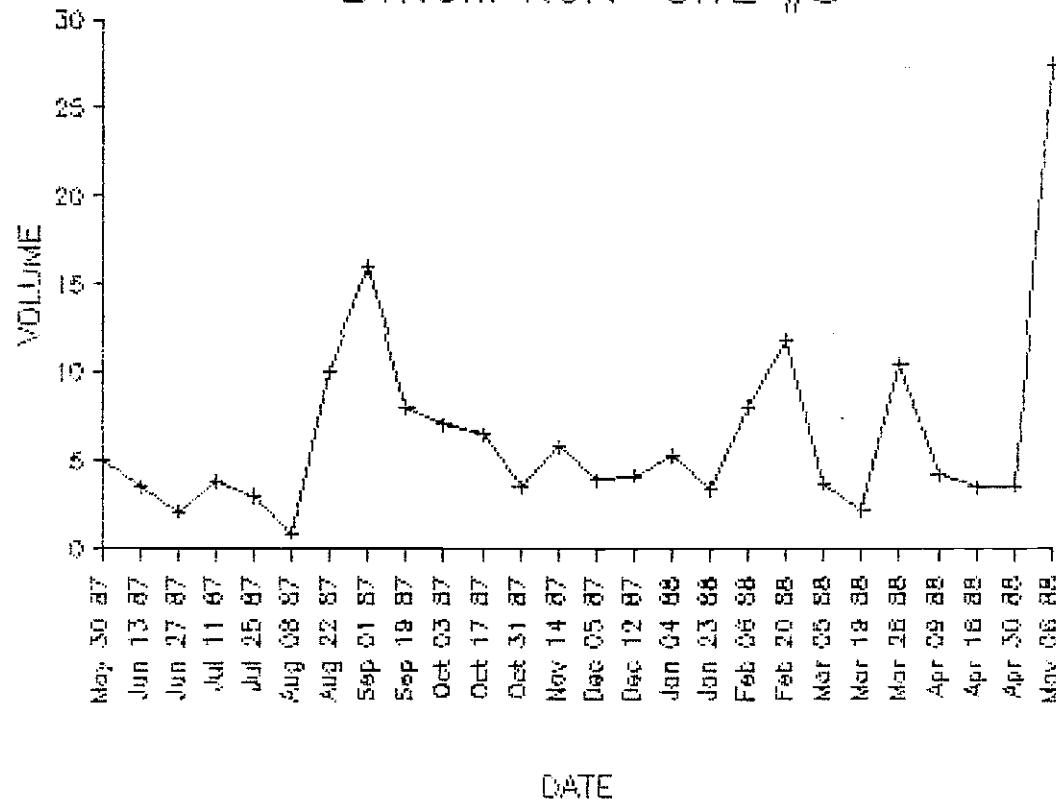




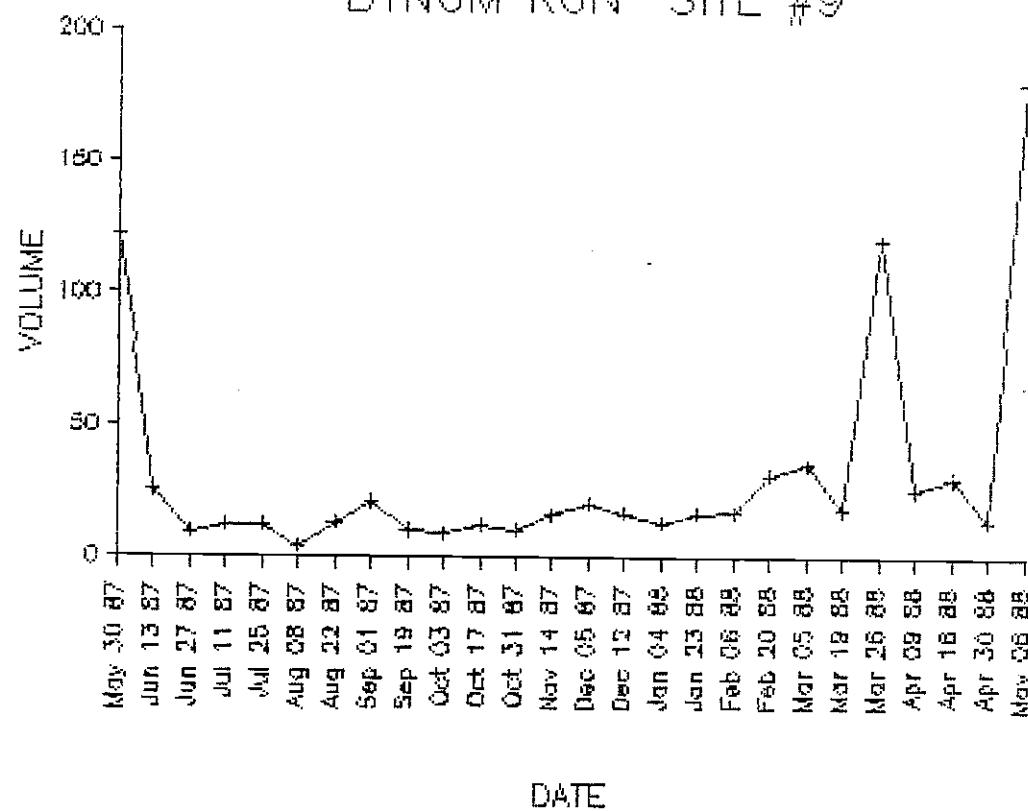
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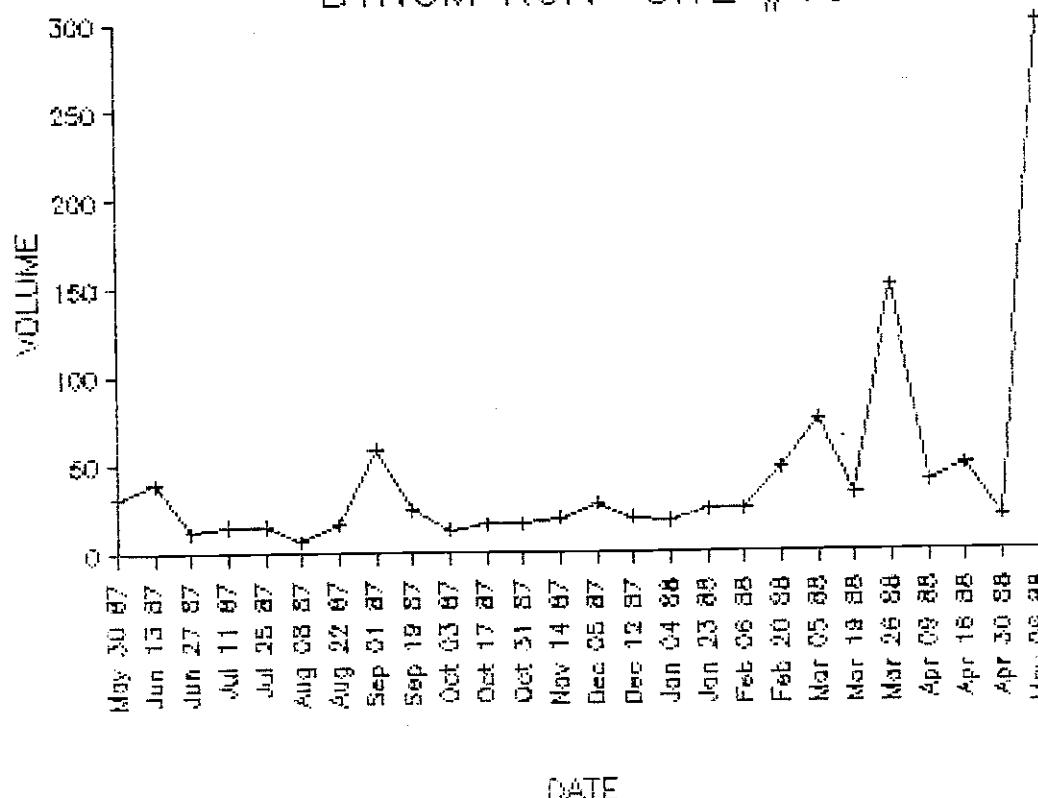
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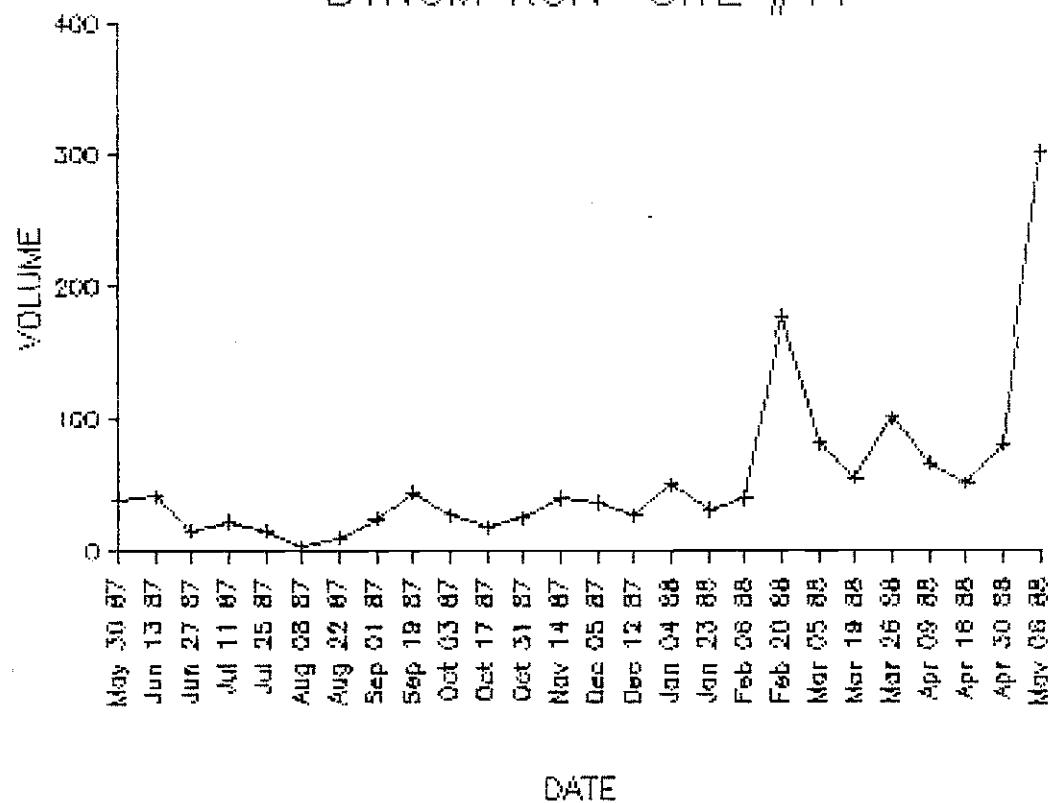
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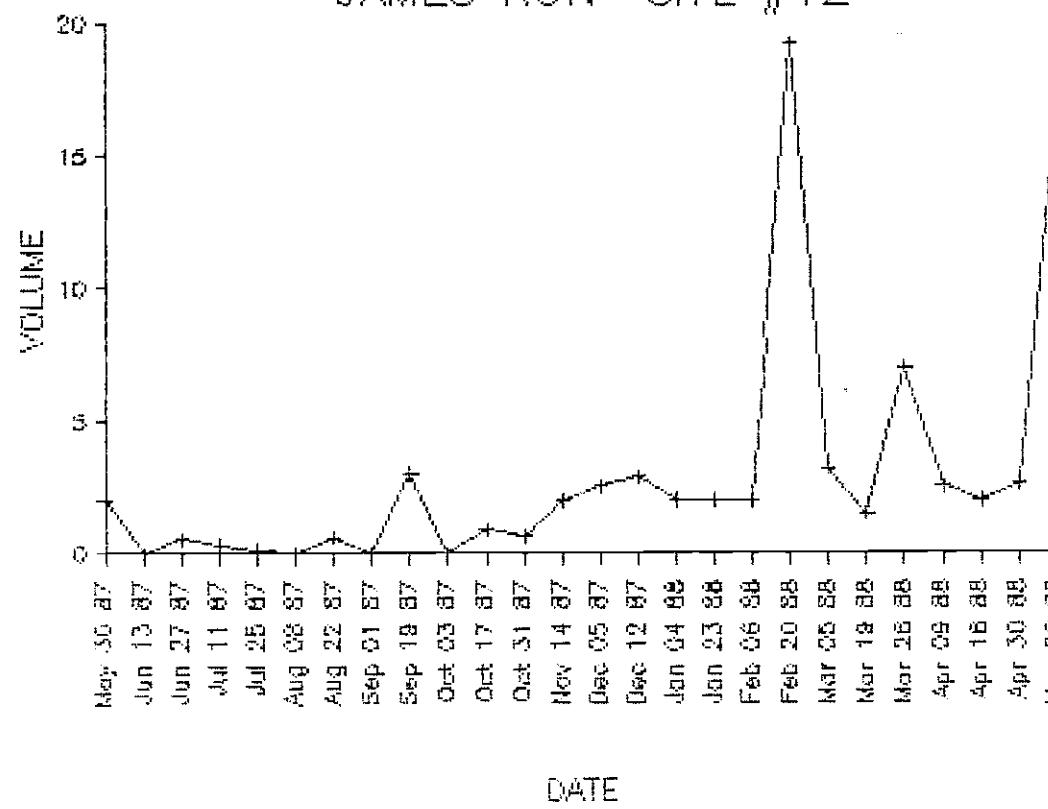
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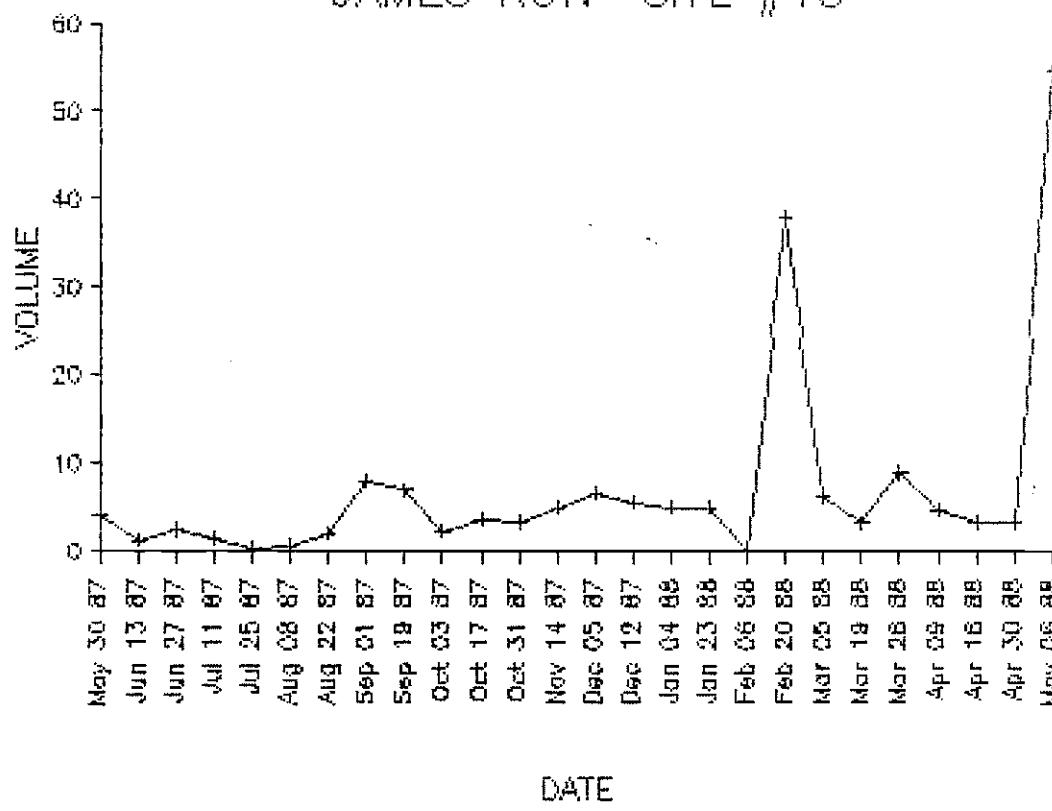
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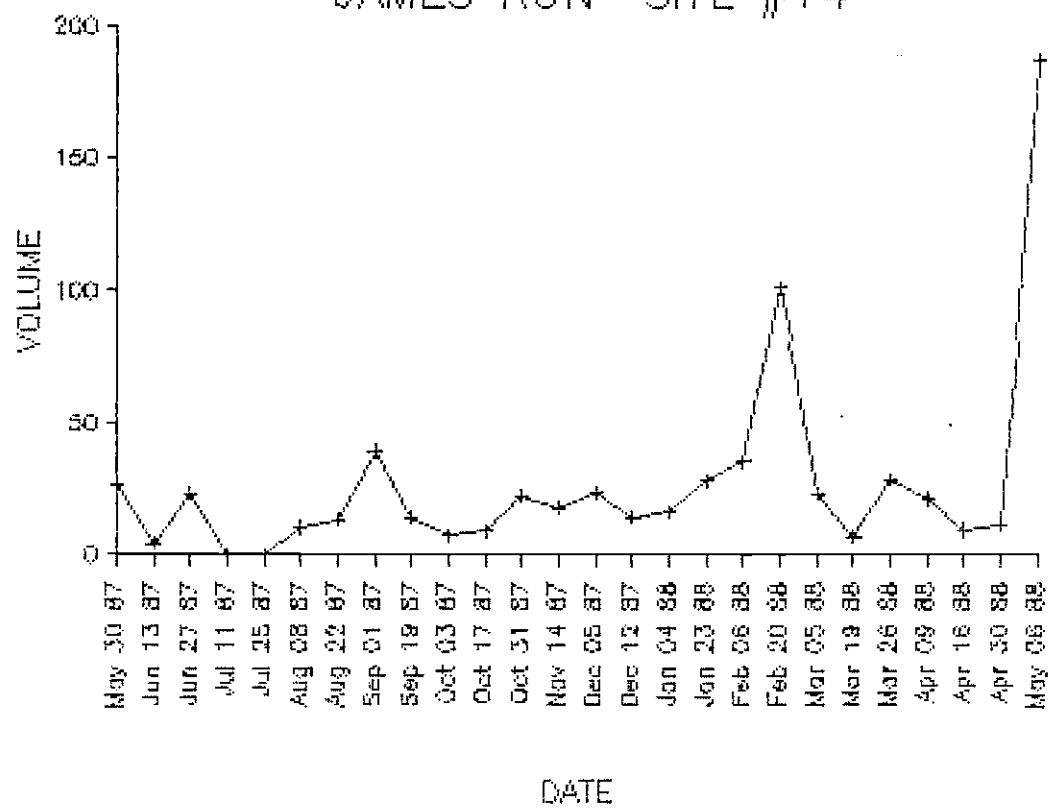
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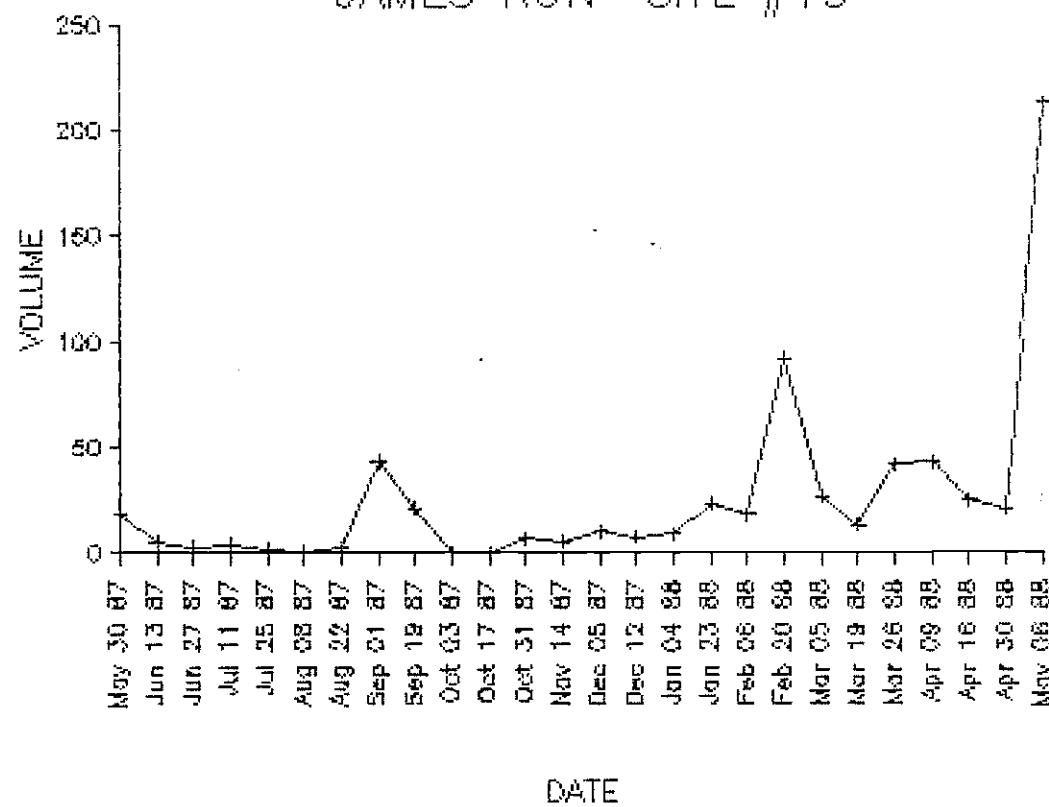
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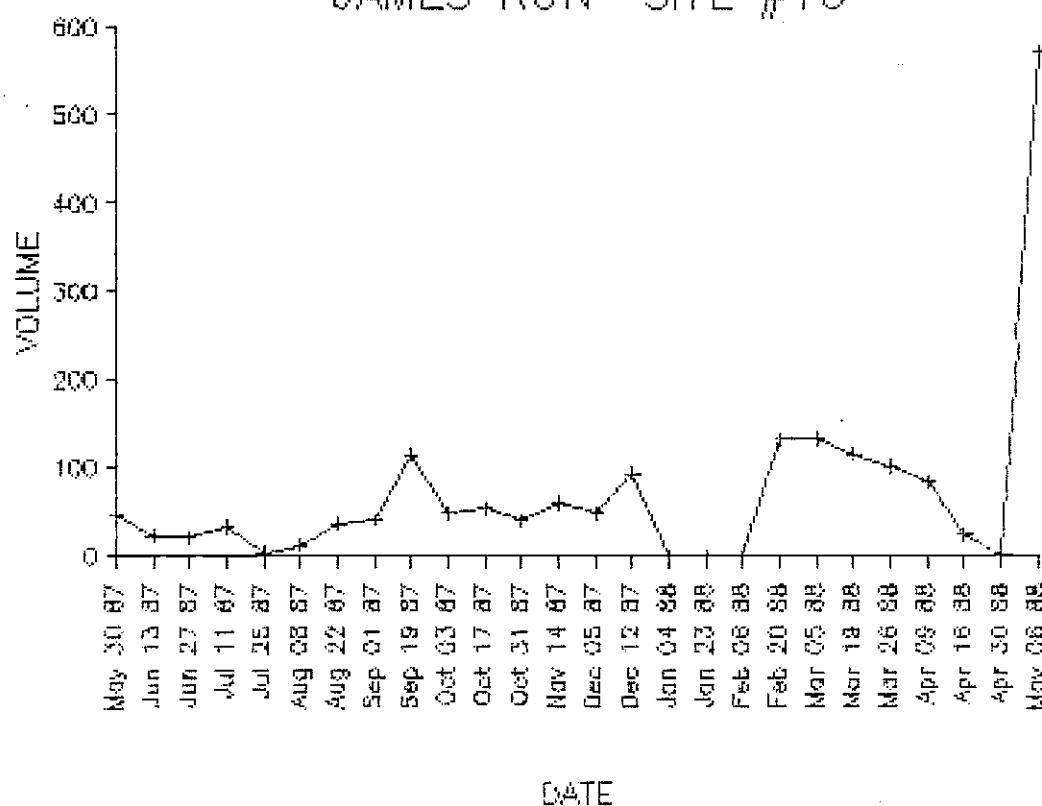
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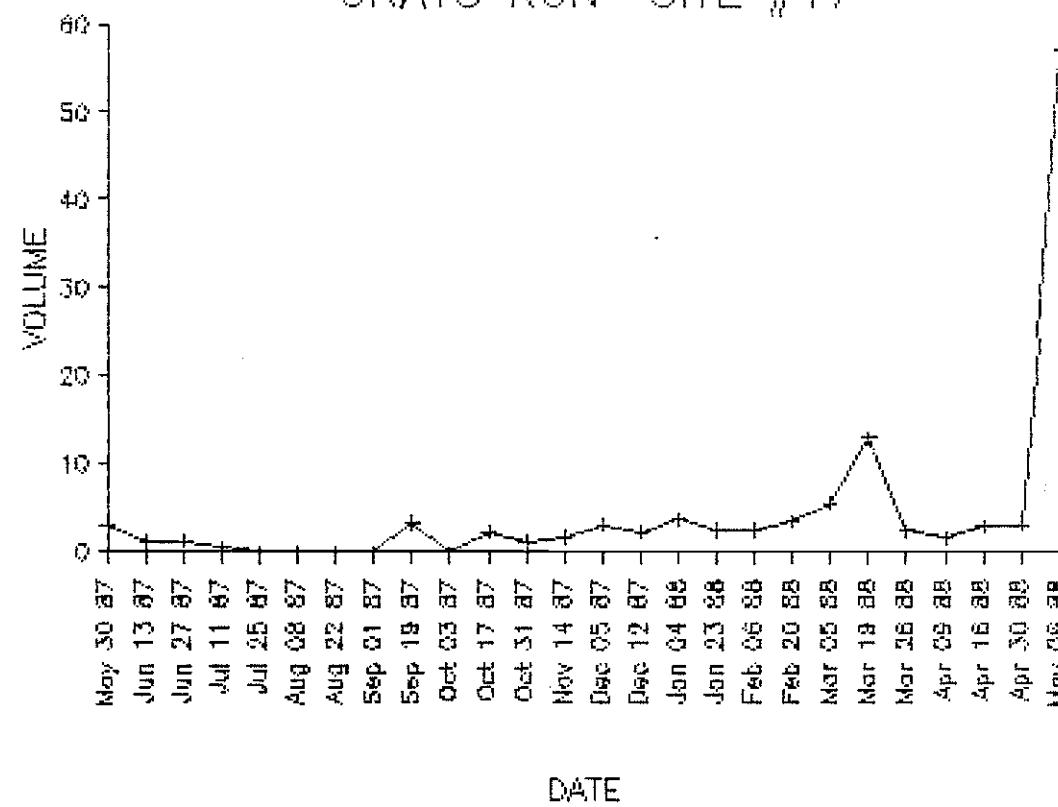
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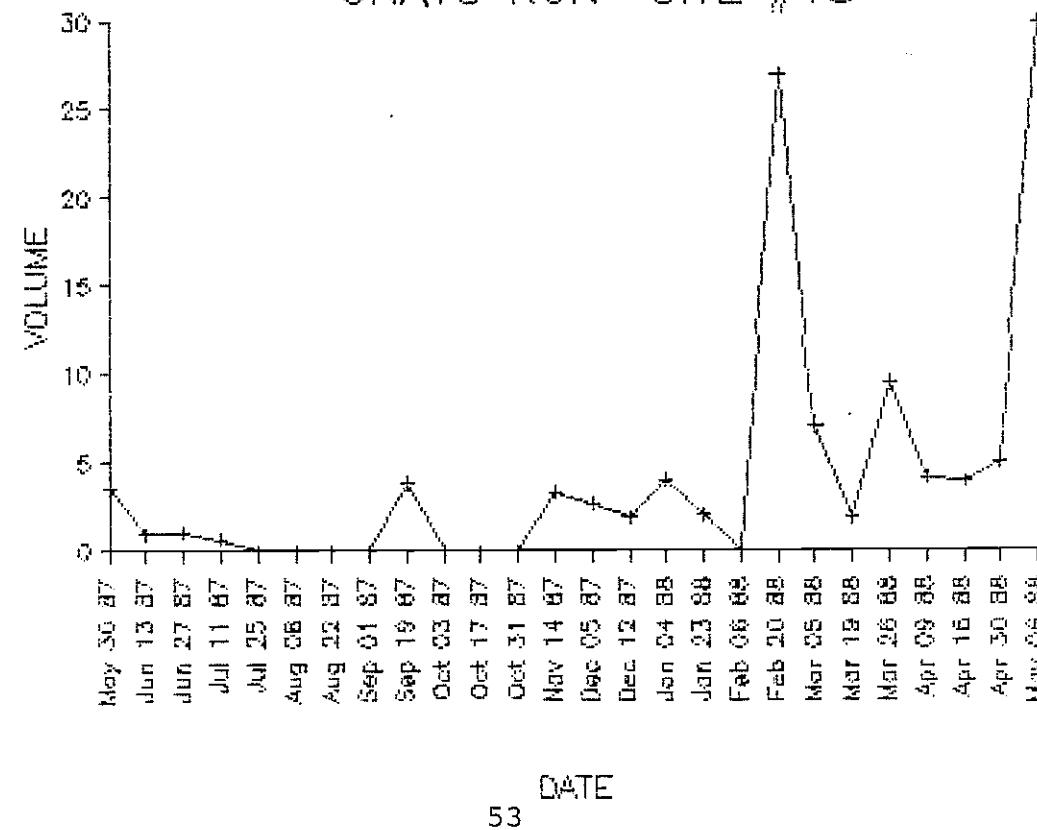
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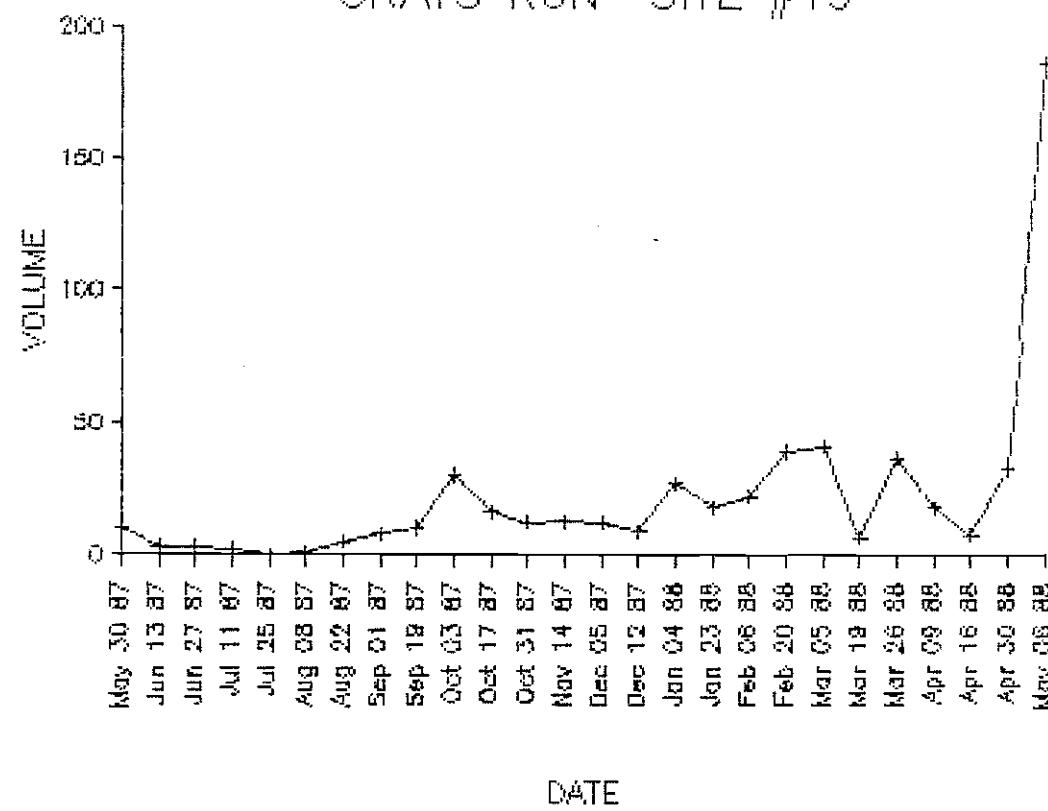
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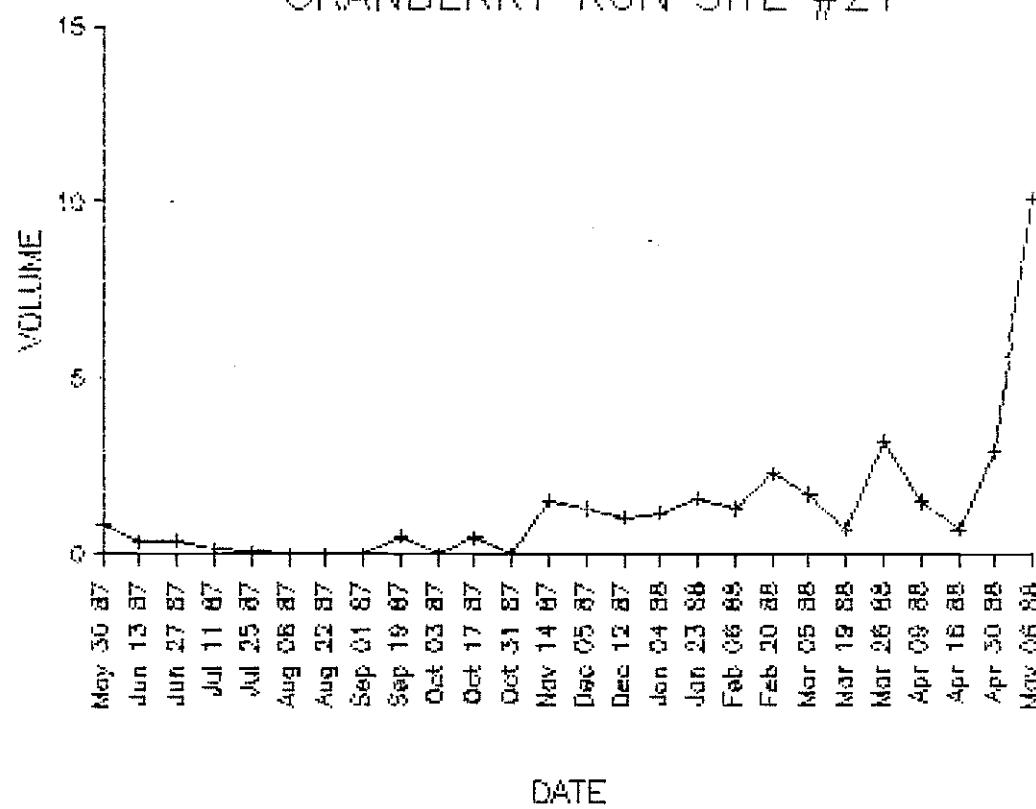
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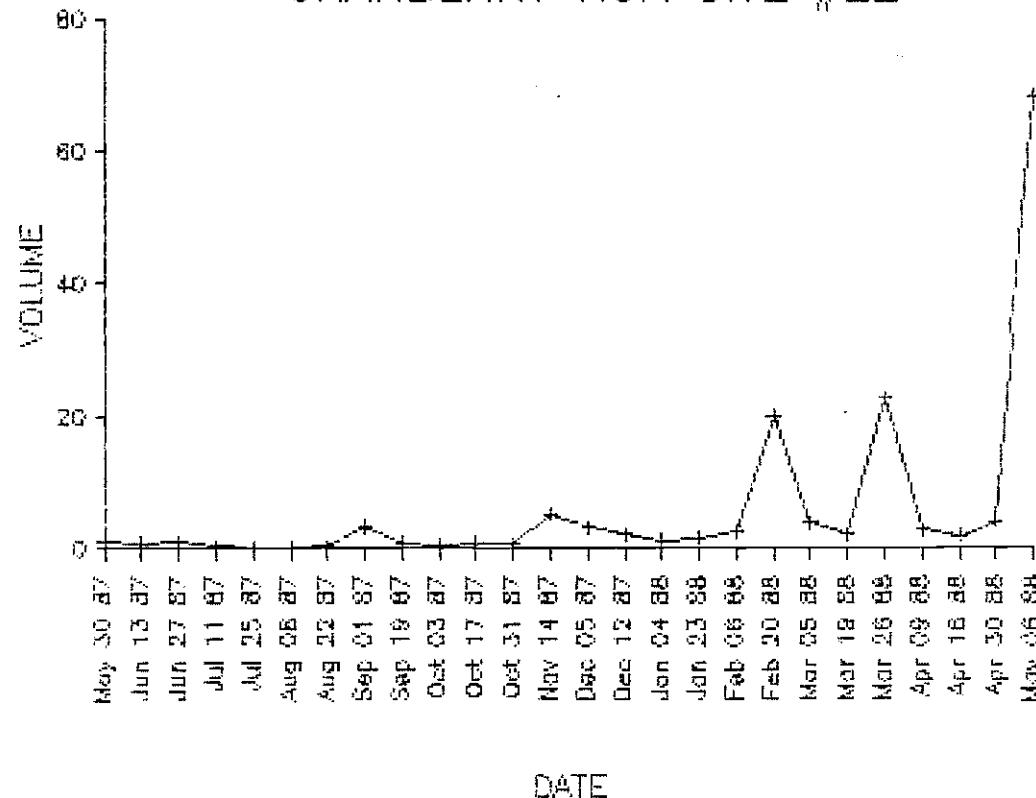
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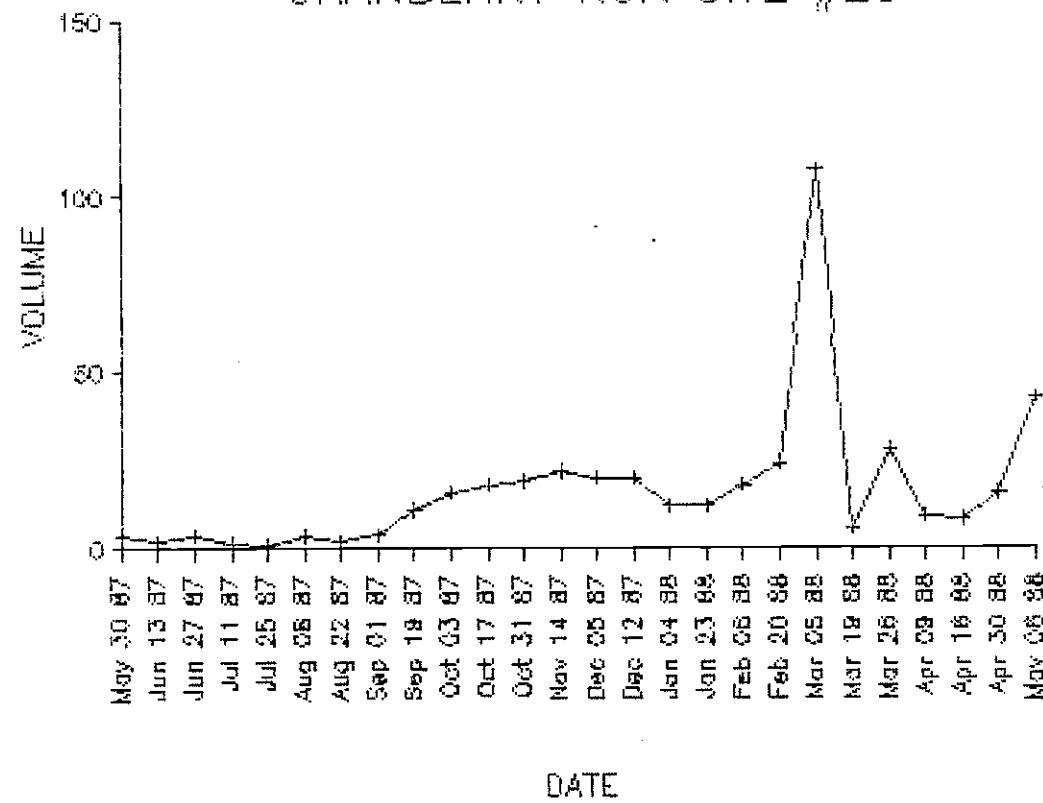
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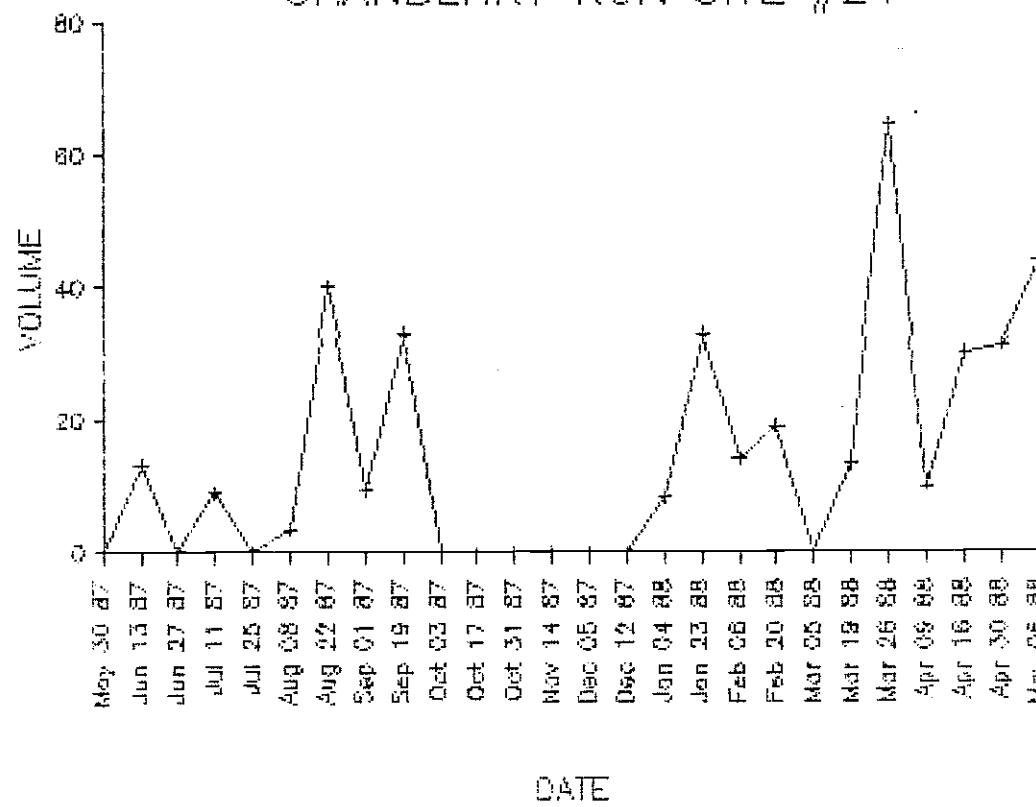
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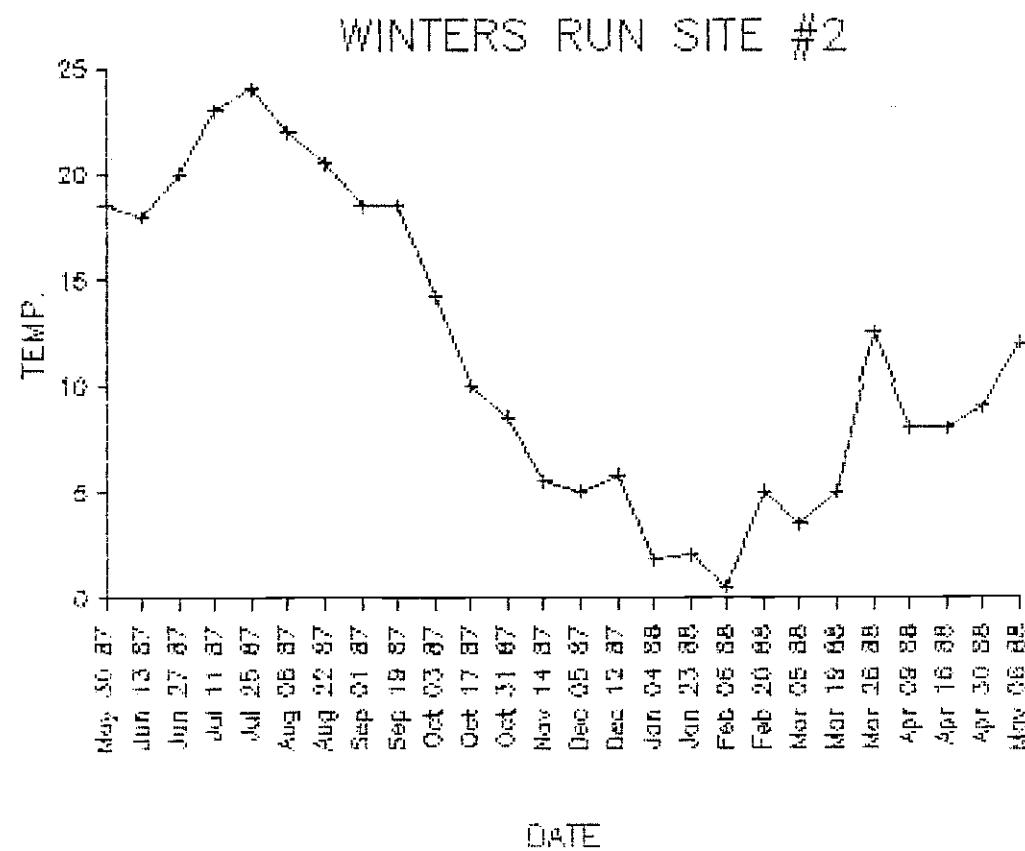
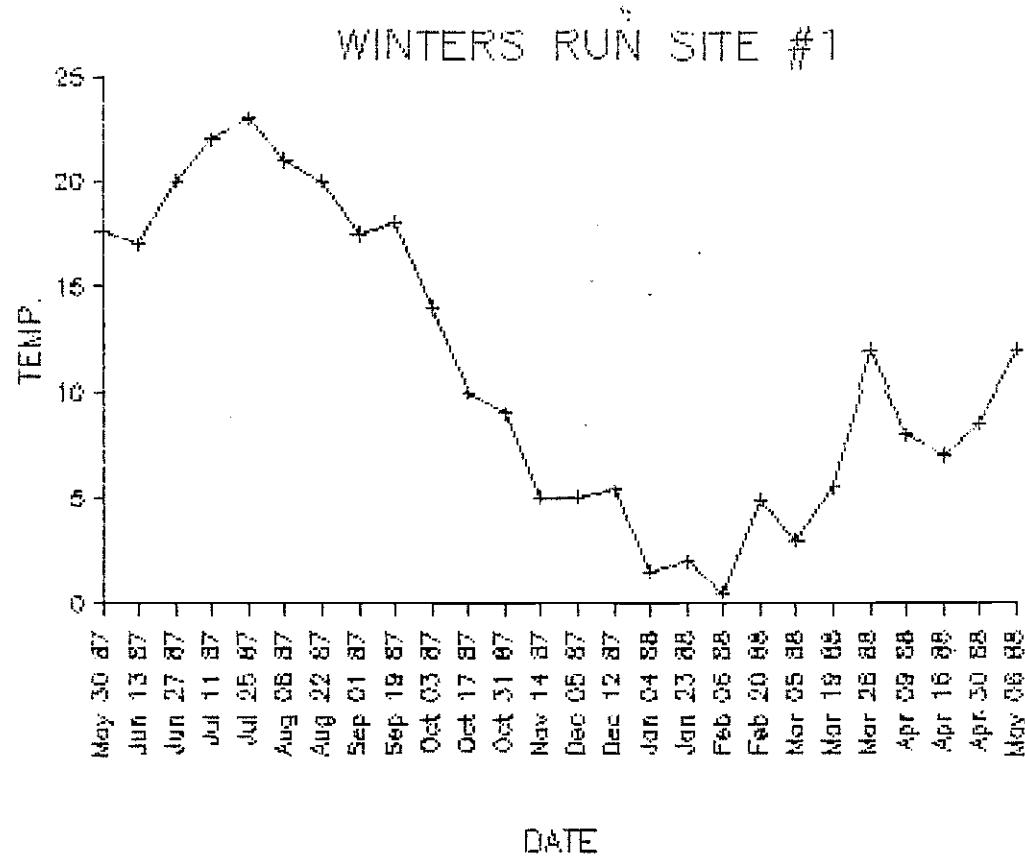
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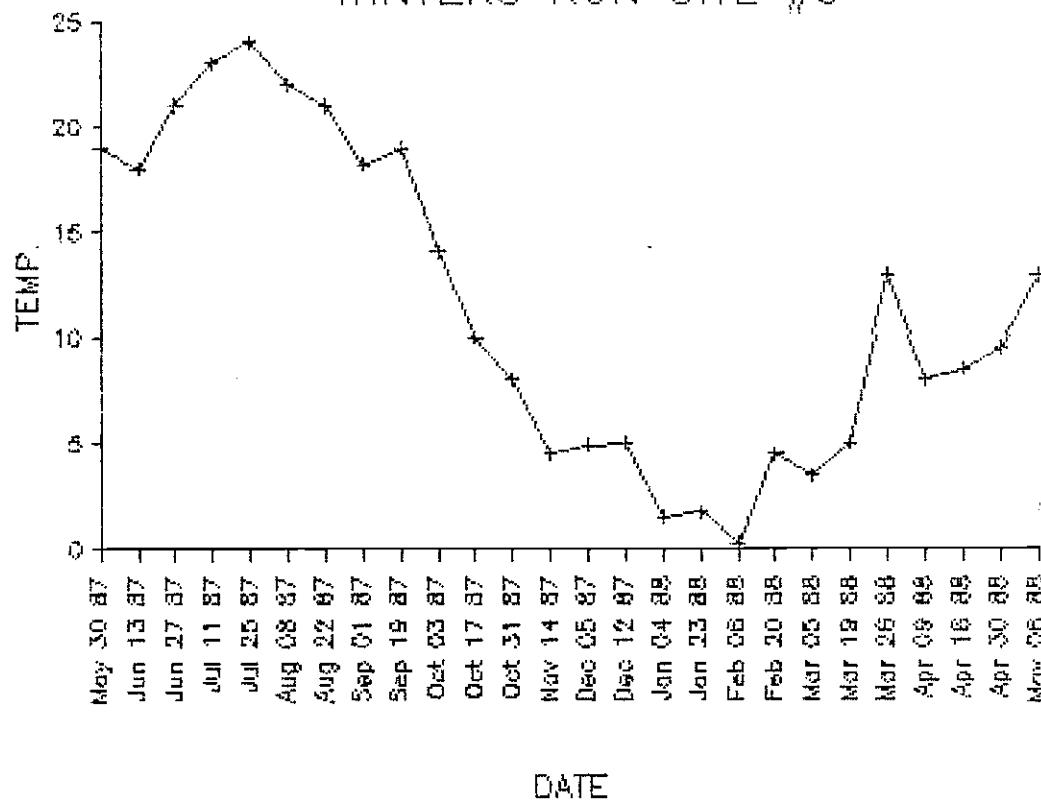
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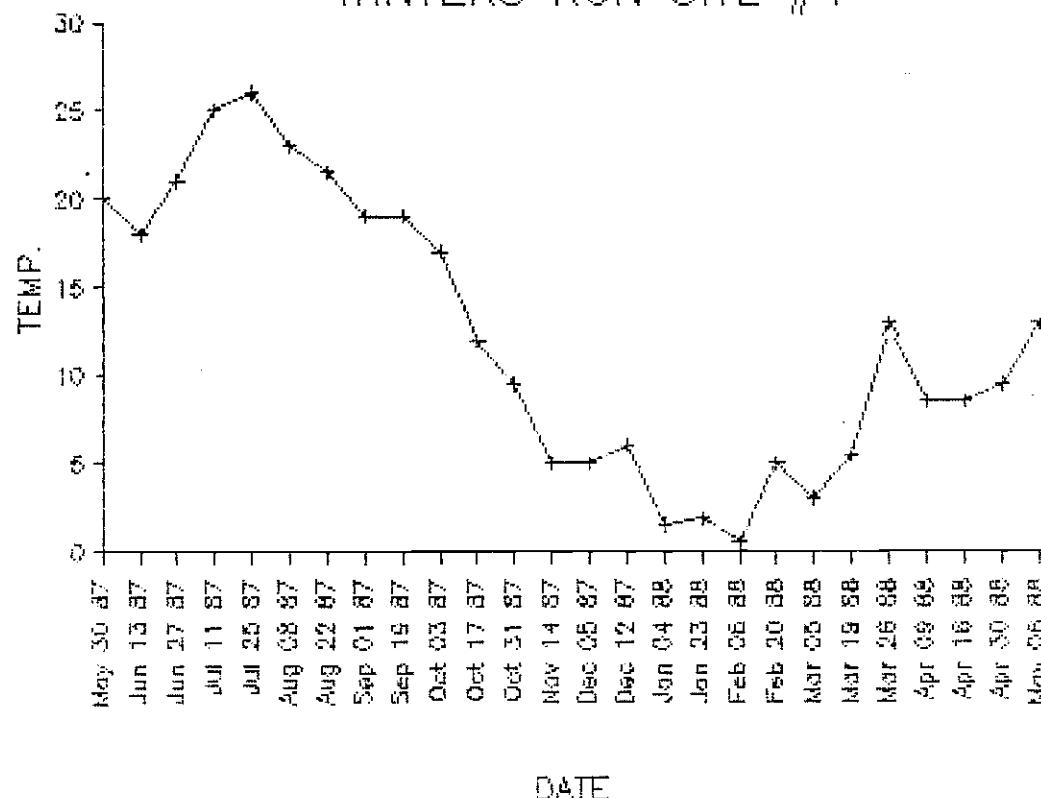
Temperature
(Degrees Celsius)

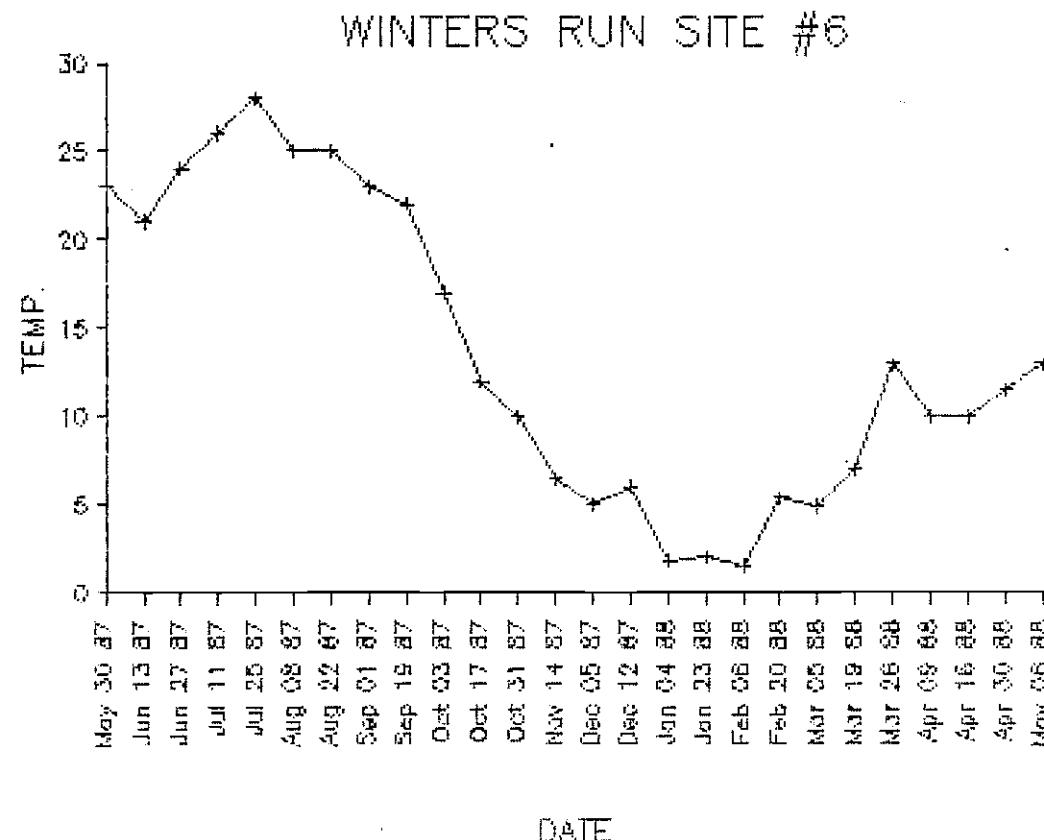
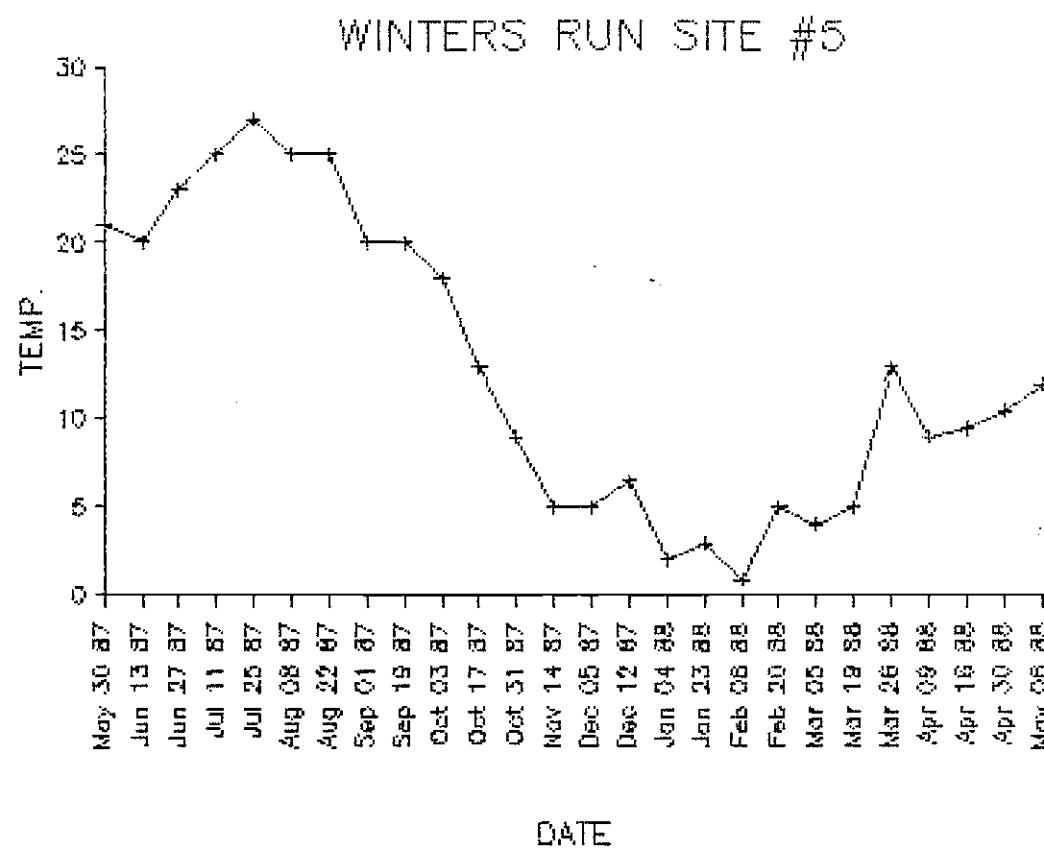


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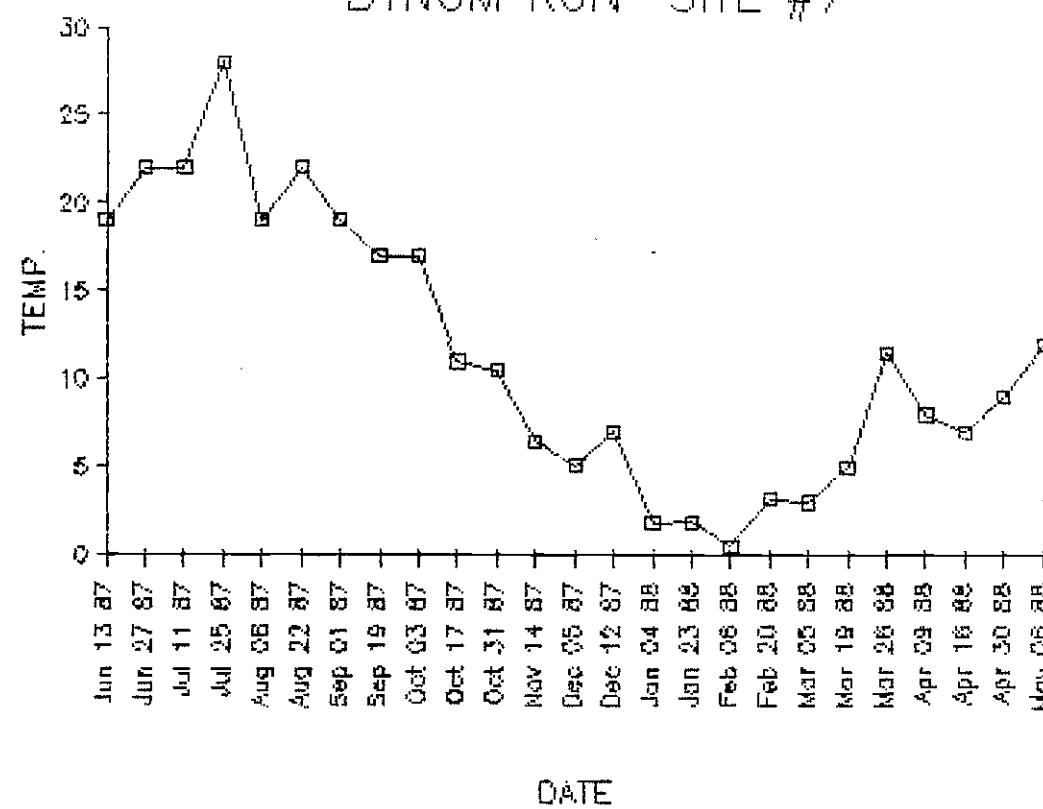


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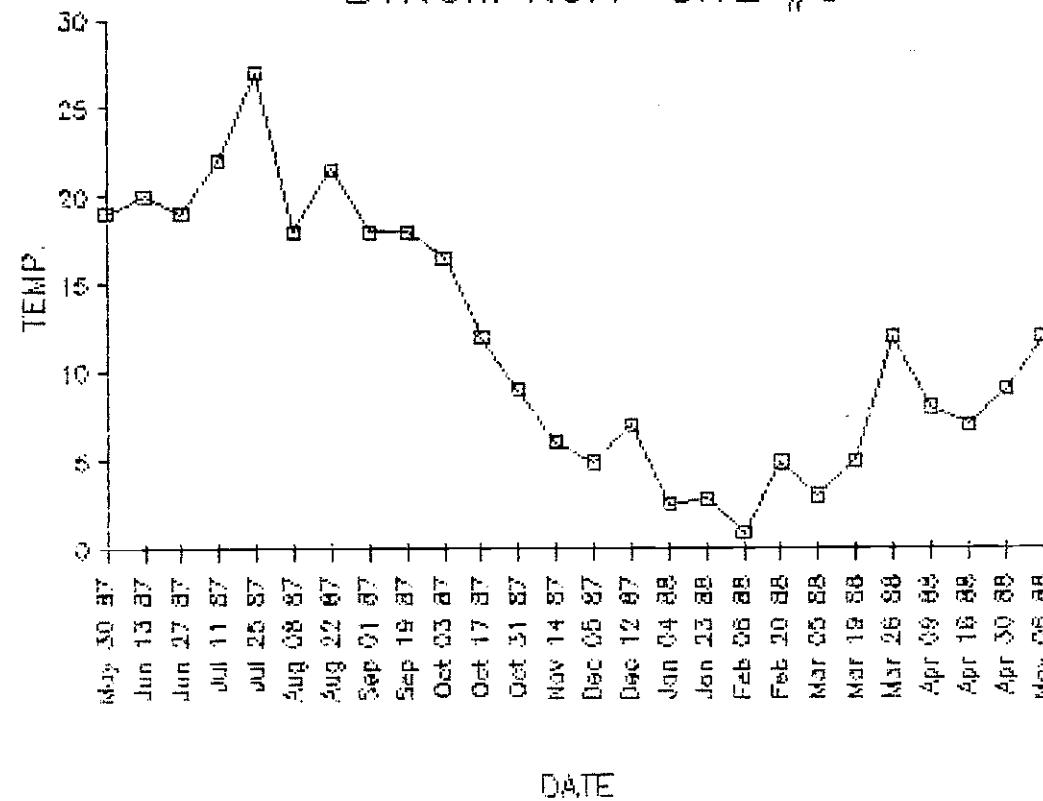




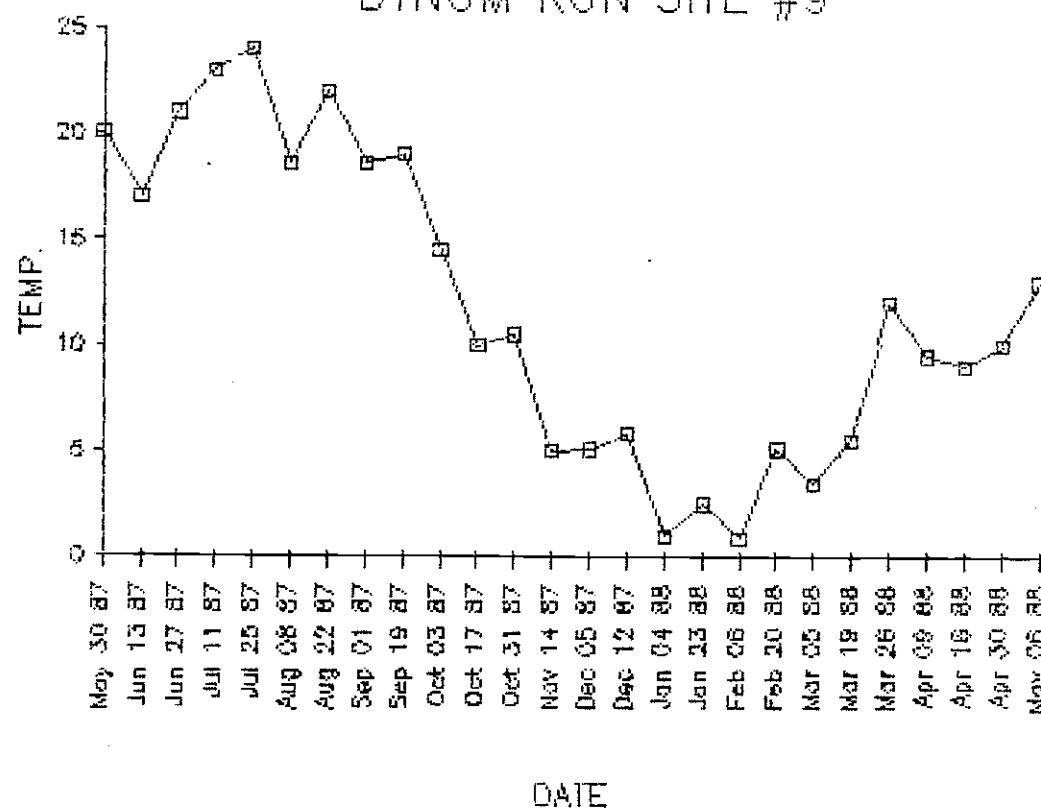
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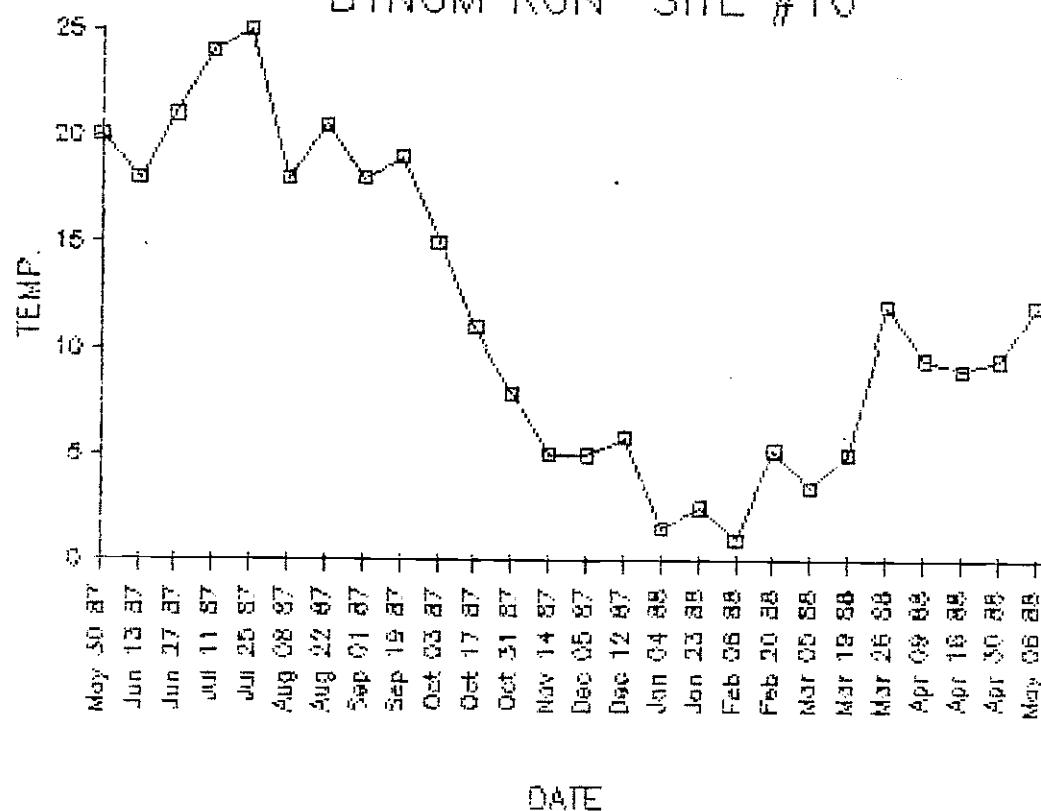
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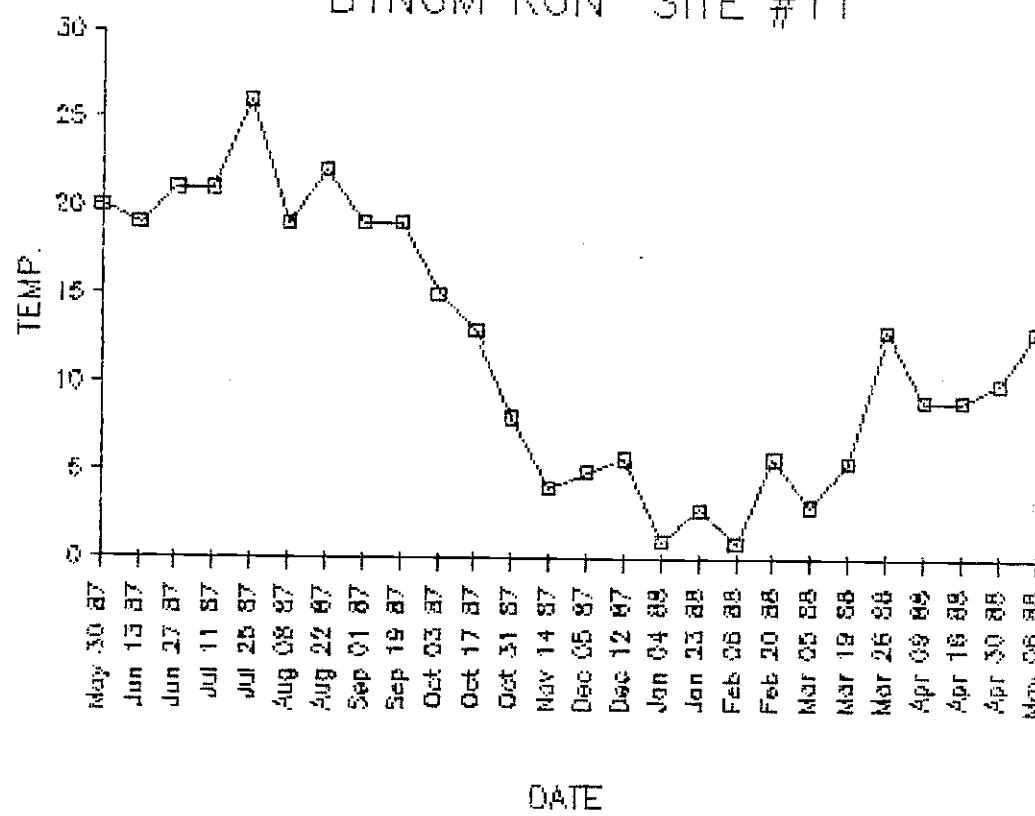
BYNUM RUN SITE #9



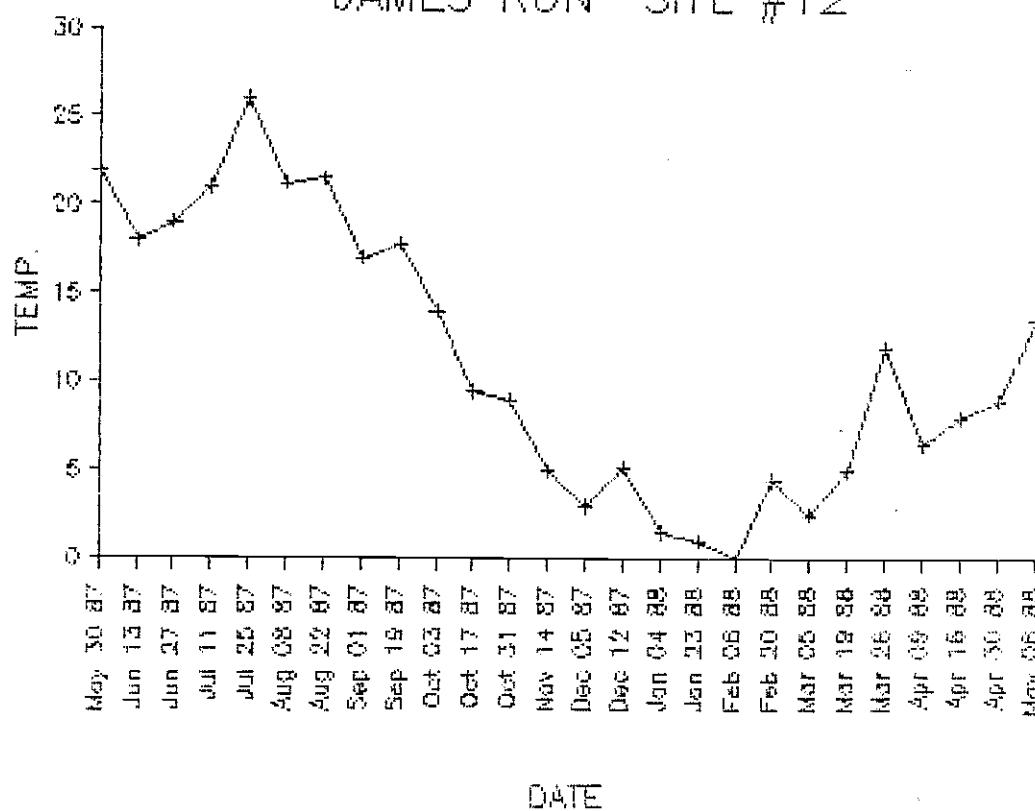
BYNUM RUN SITE #10



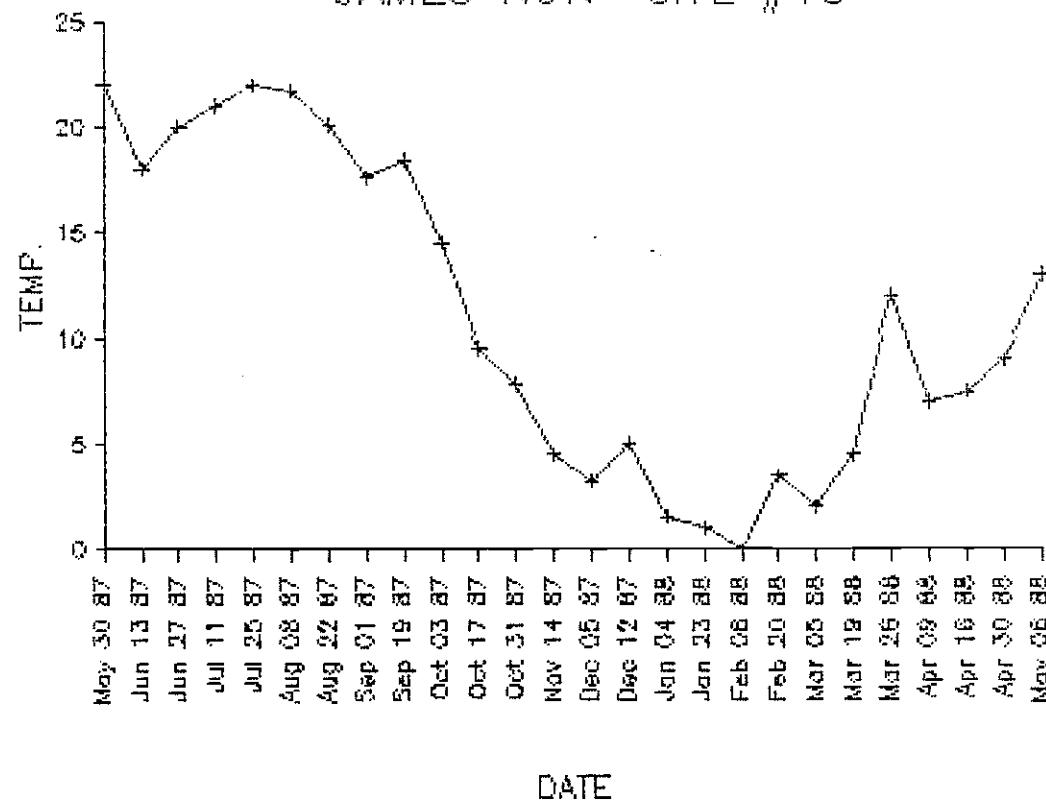
BYNUM RUN SITE #11



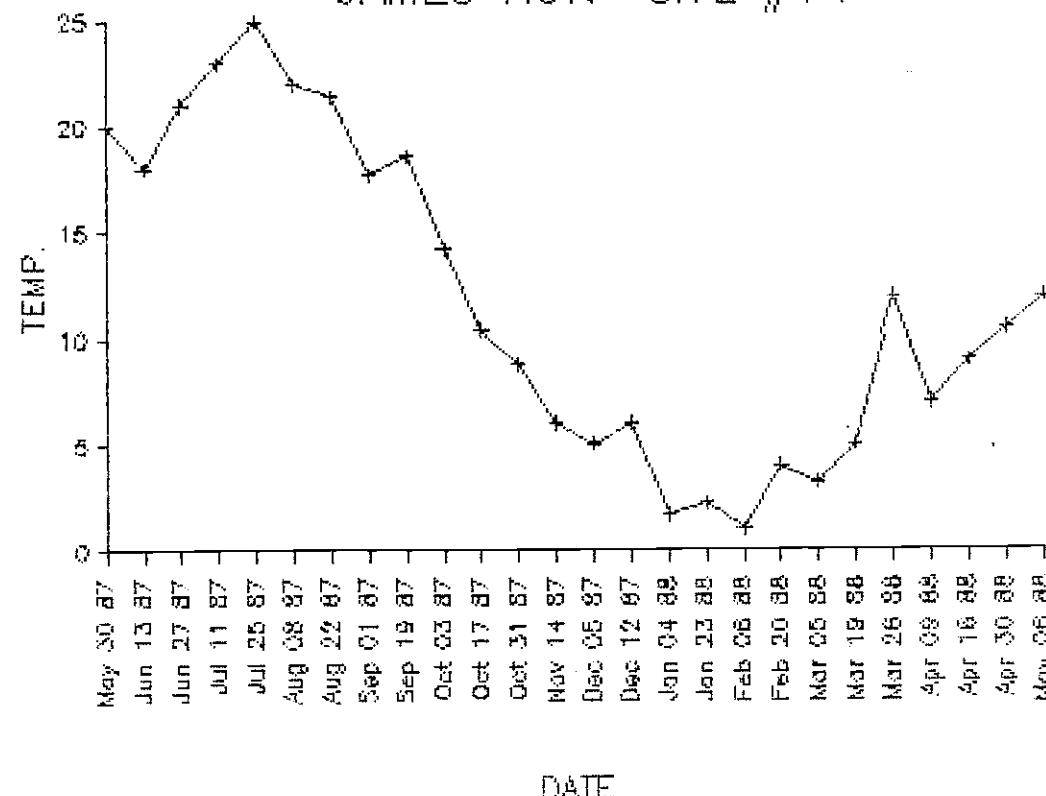
JAMES RUN SITE #12



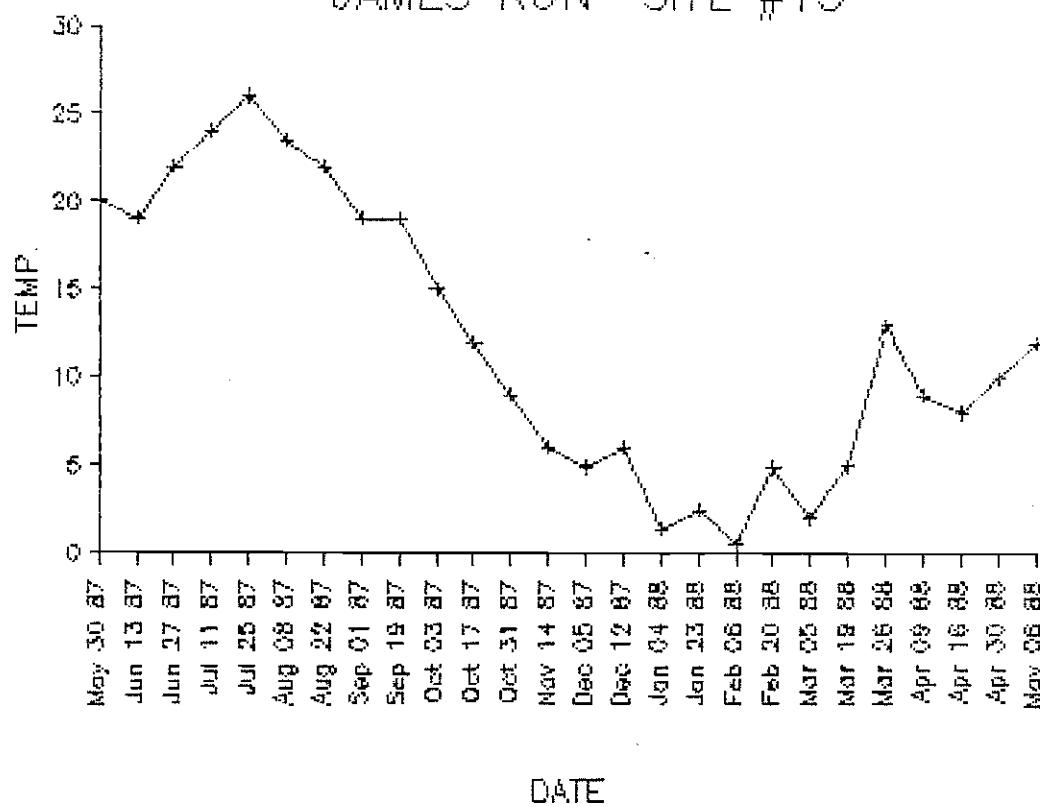
JAMES RUN SITE #13



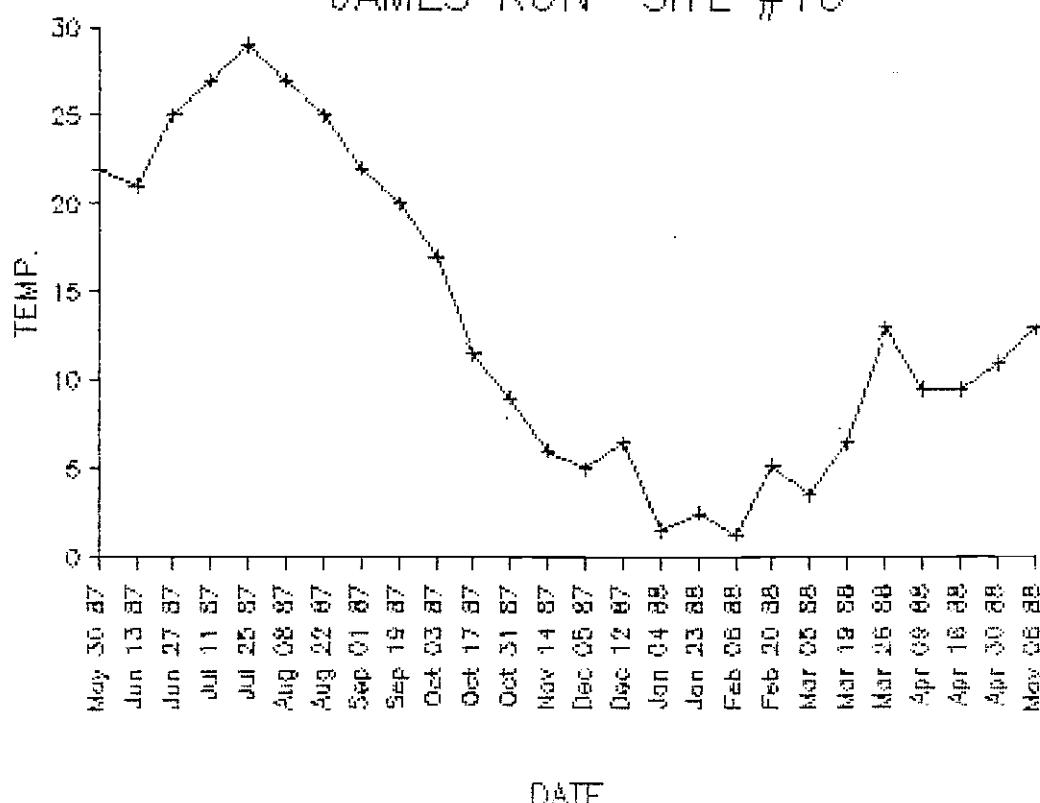
JAMES RUN SITE #14



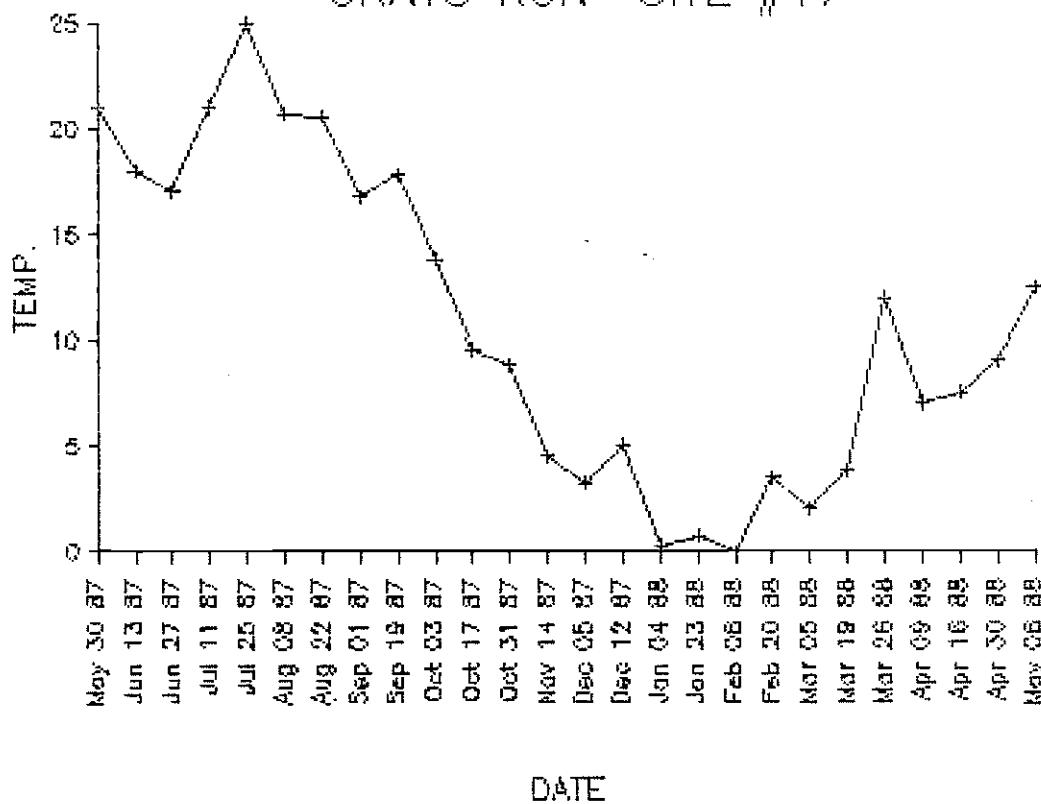
JAMES RUN SITE #15



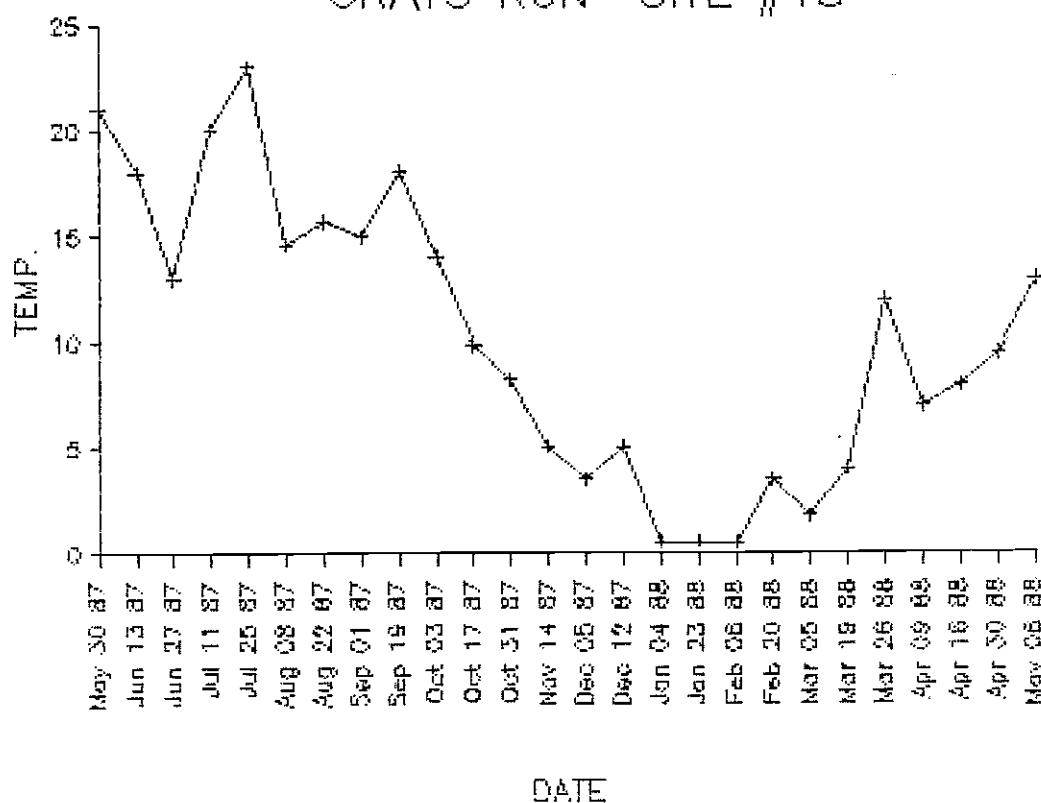
JAMES RUN SITE #16



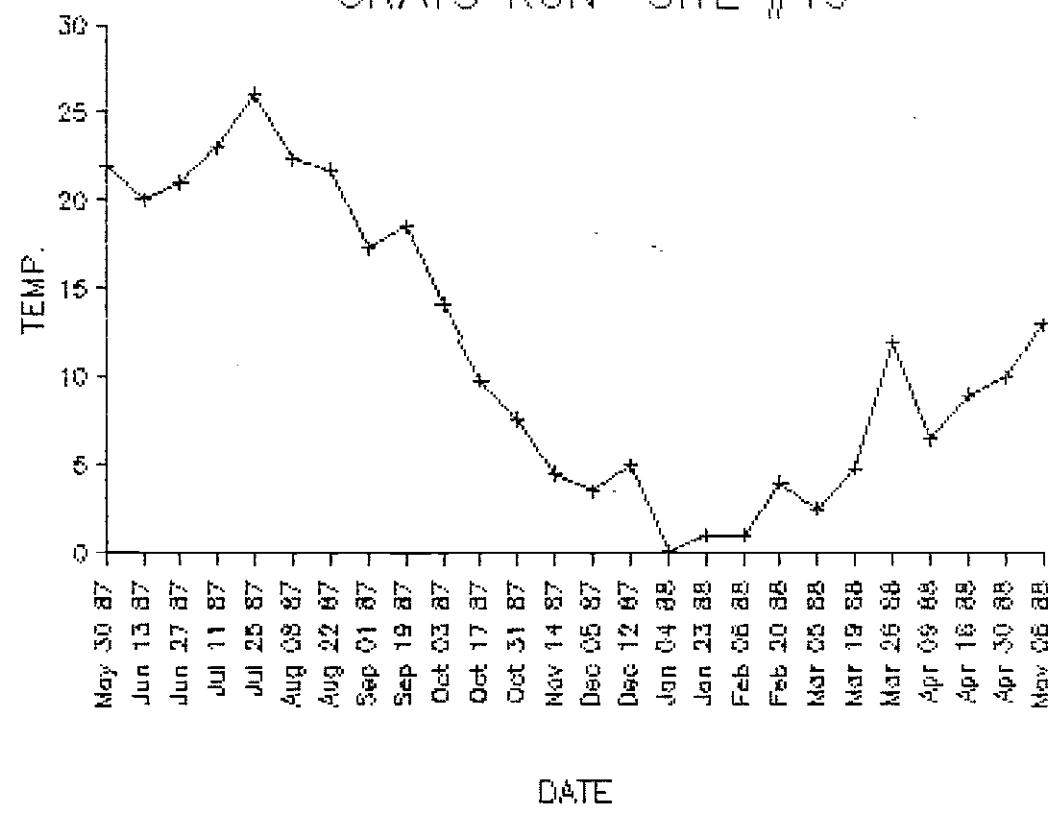
GRAYS RUN SITE #17



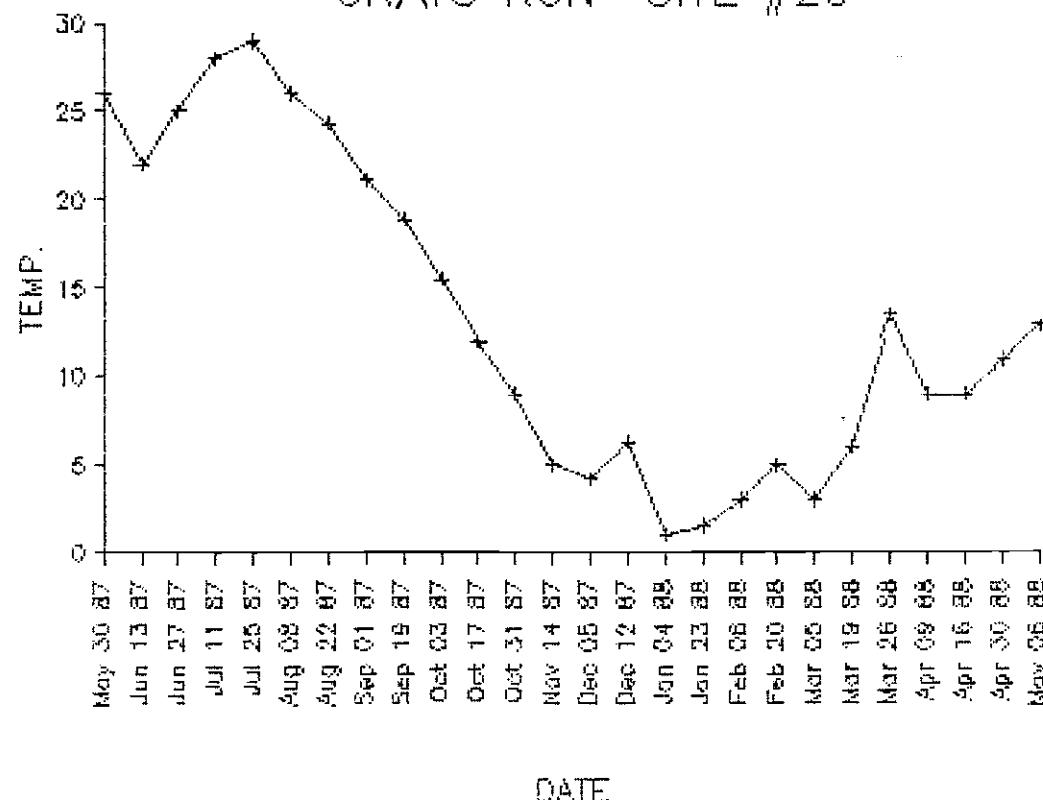
GRAYS RUN SITE #18



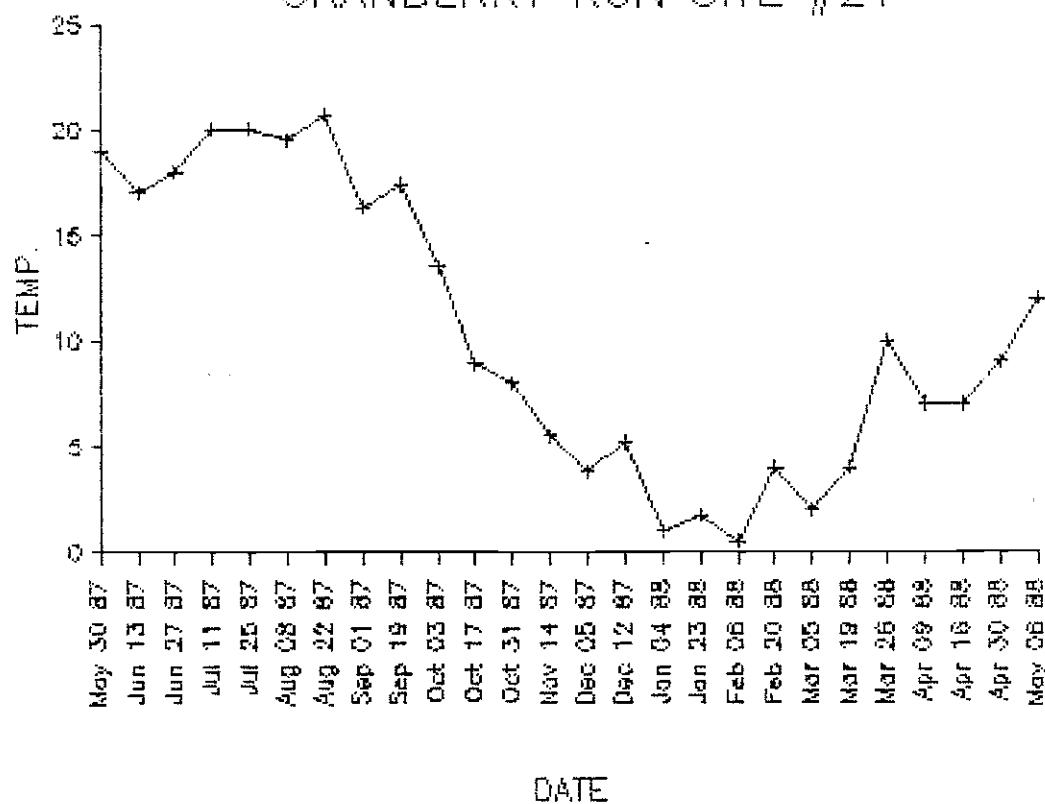
GRAYS RUN SITE #19



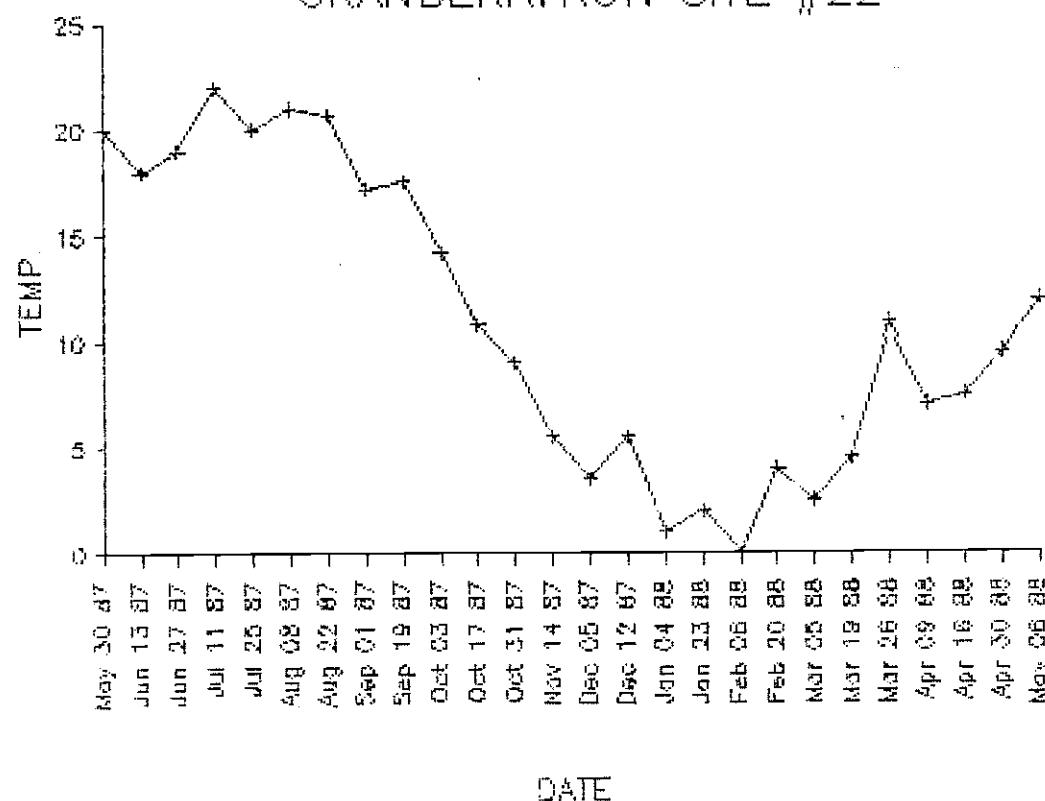
GRAYS RUN SITE #20



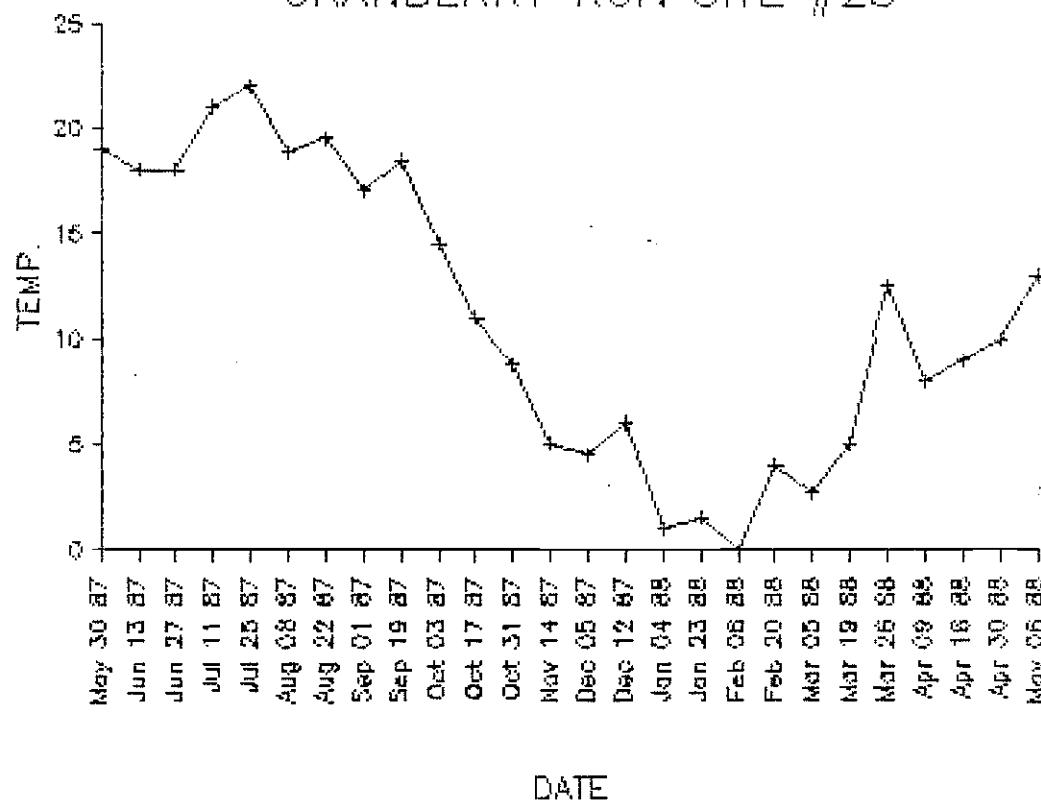
CRANBERRY RUN SITE #21



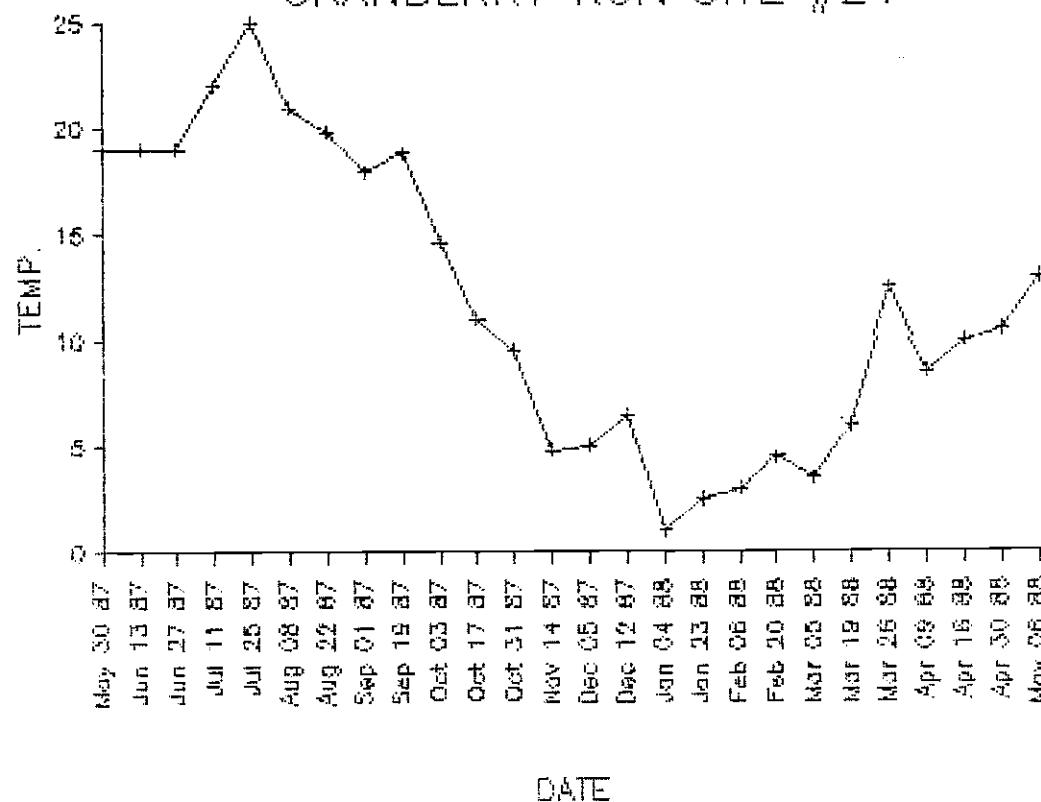
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23

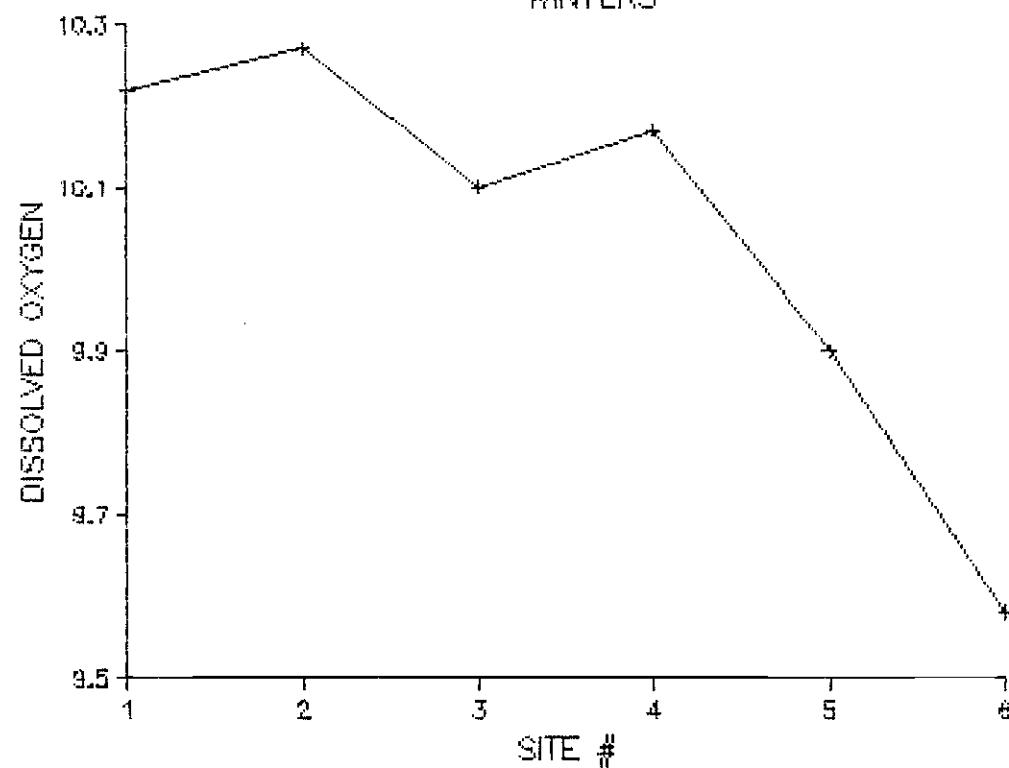


CRANBERRY RUN SITE #24

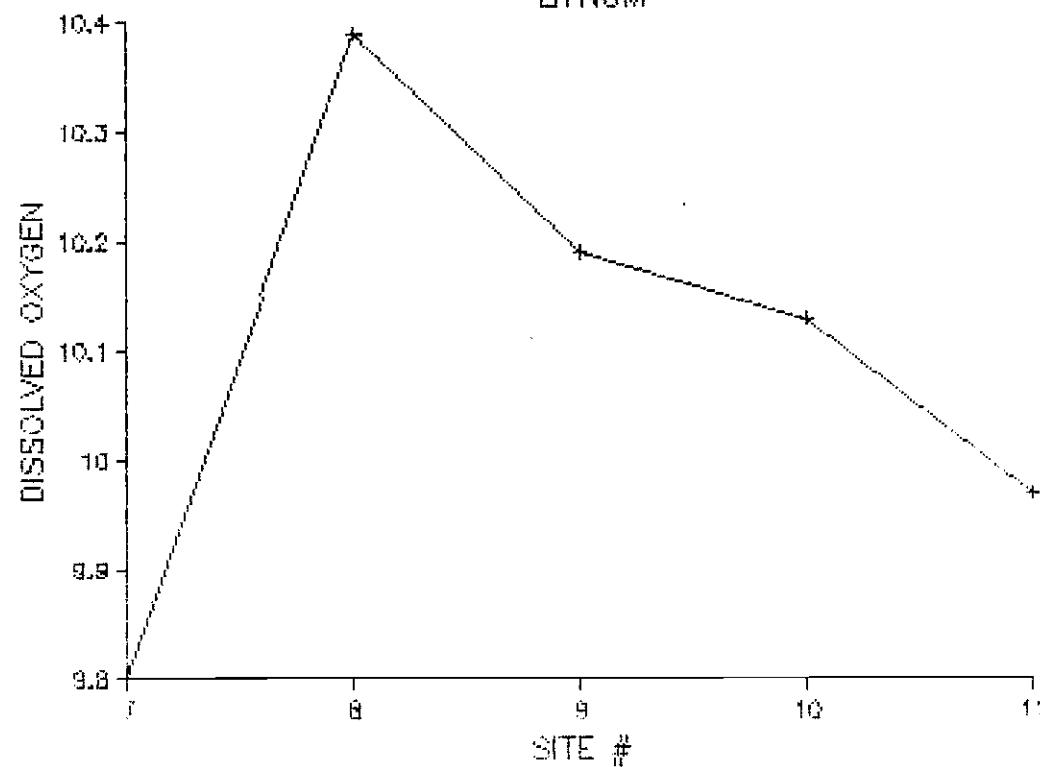


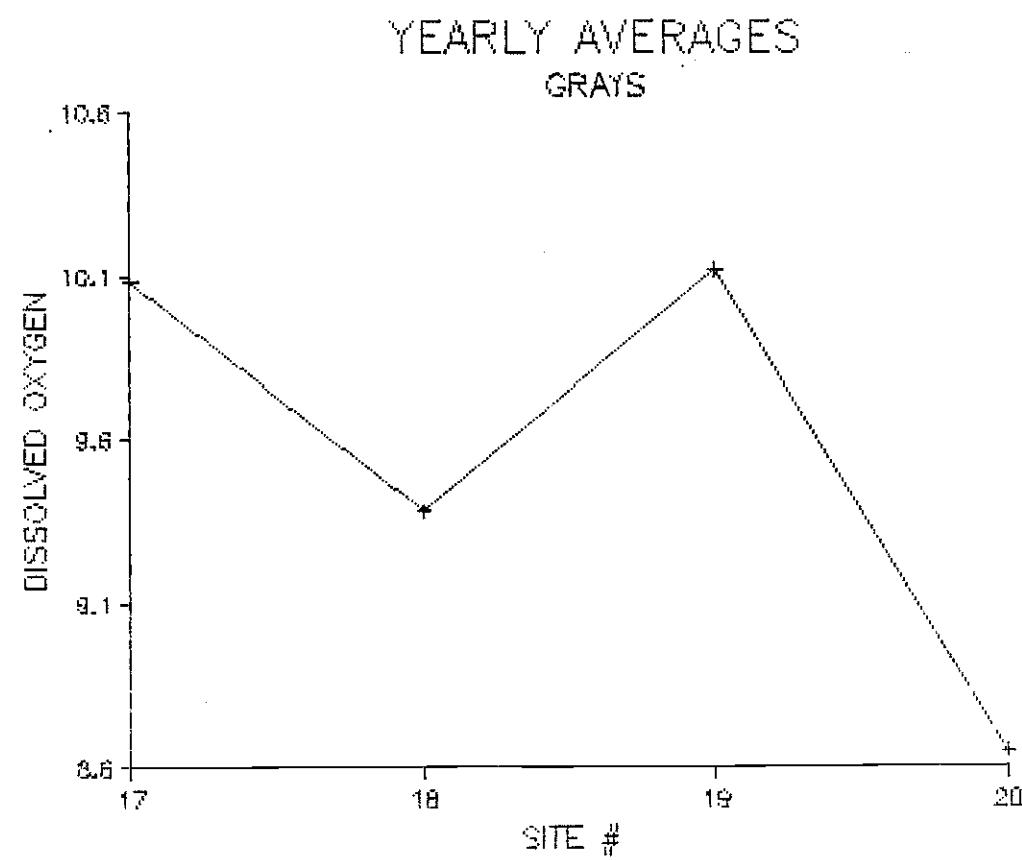
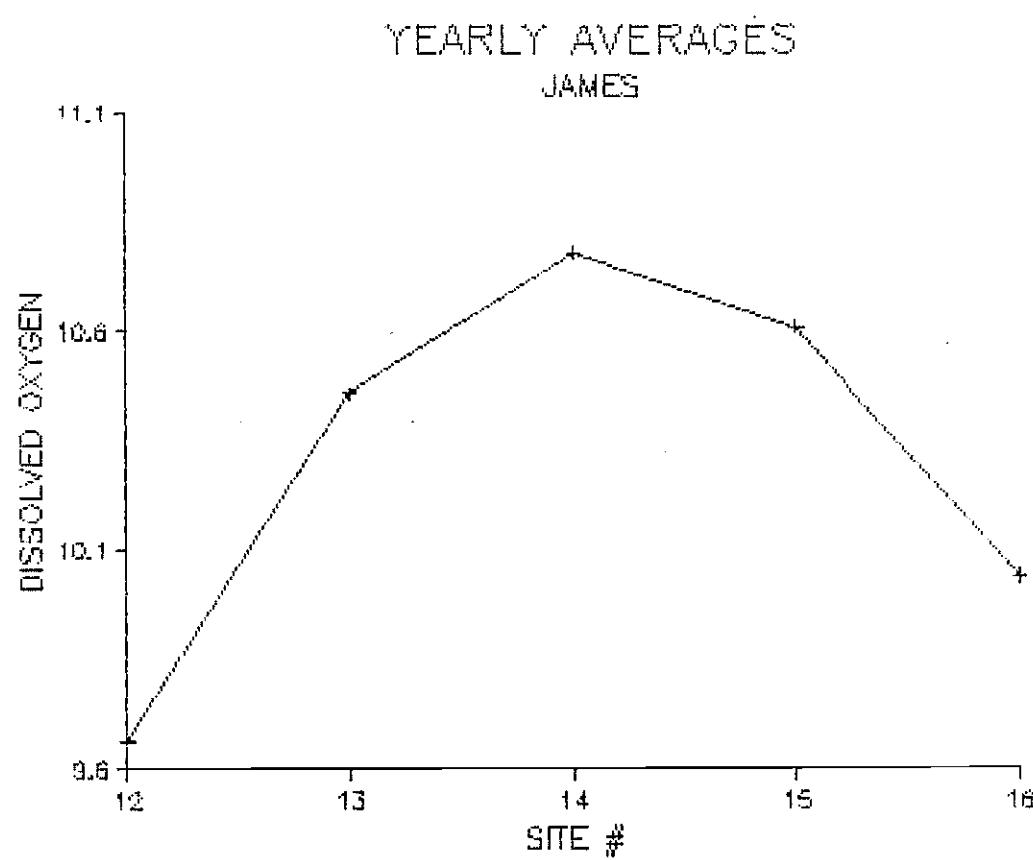
Dissolved Oxygen
(mg/l)

YEARLY AVERAGES
WINTERS

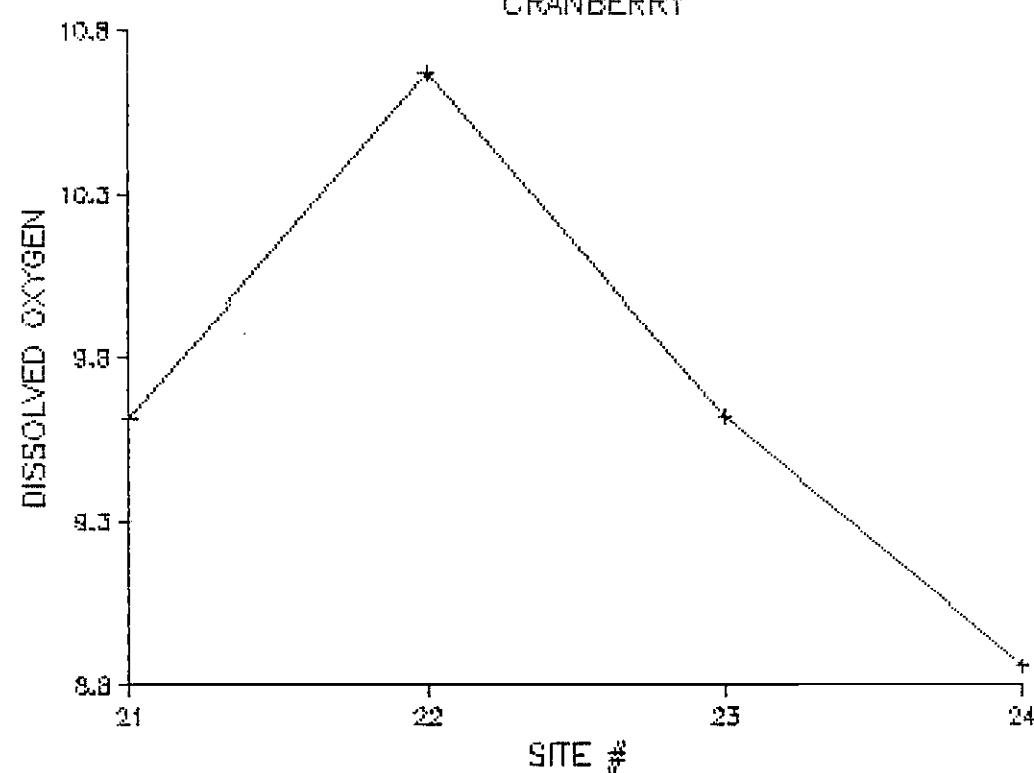


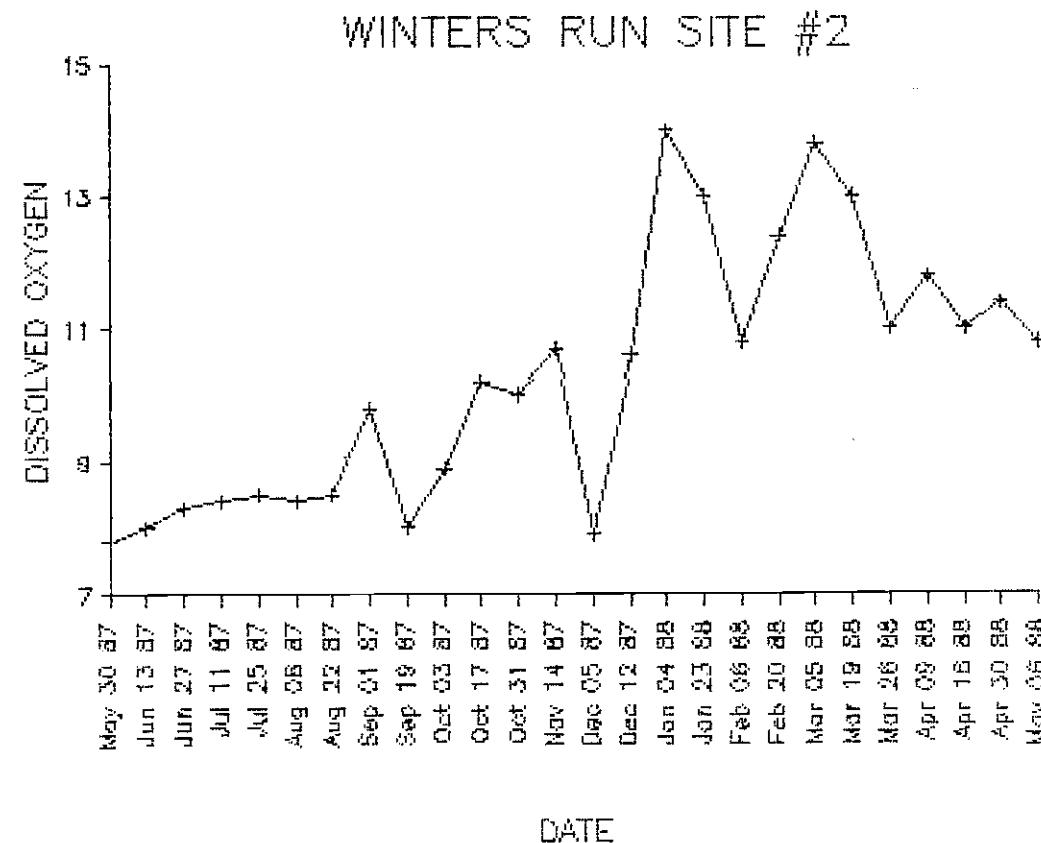
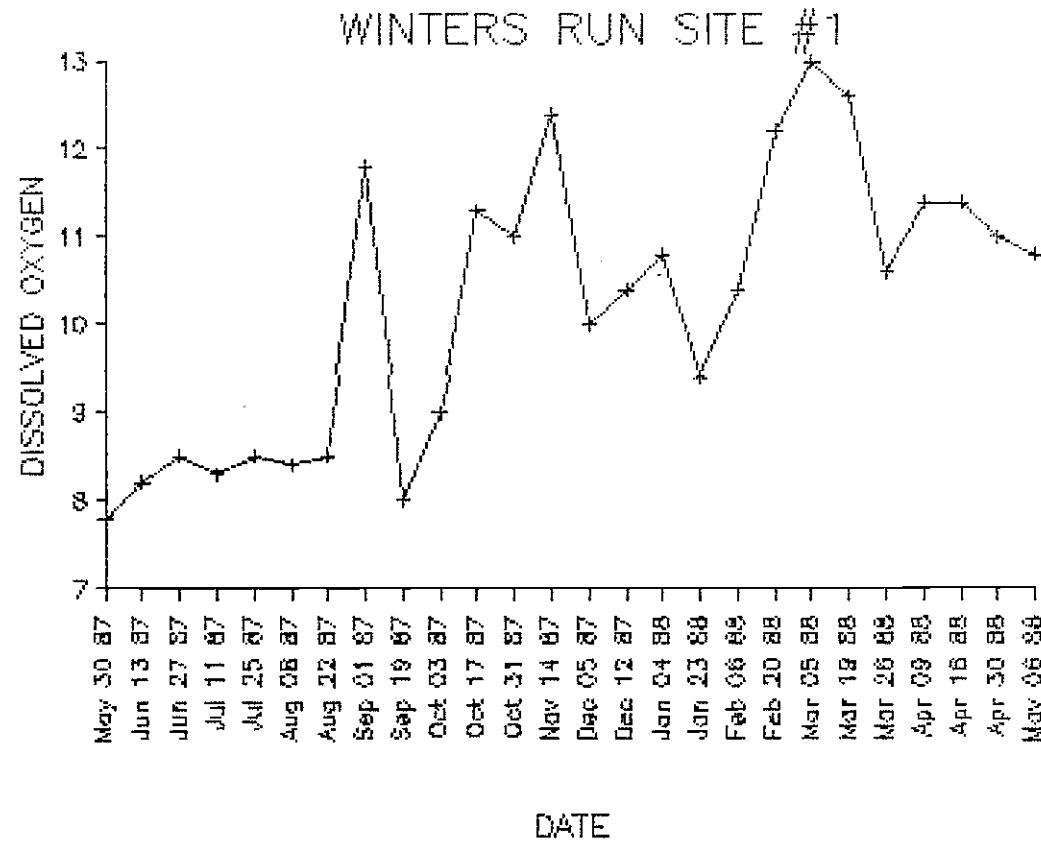
YEARLY AVERAGES
BYNUM

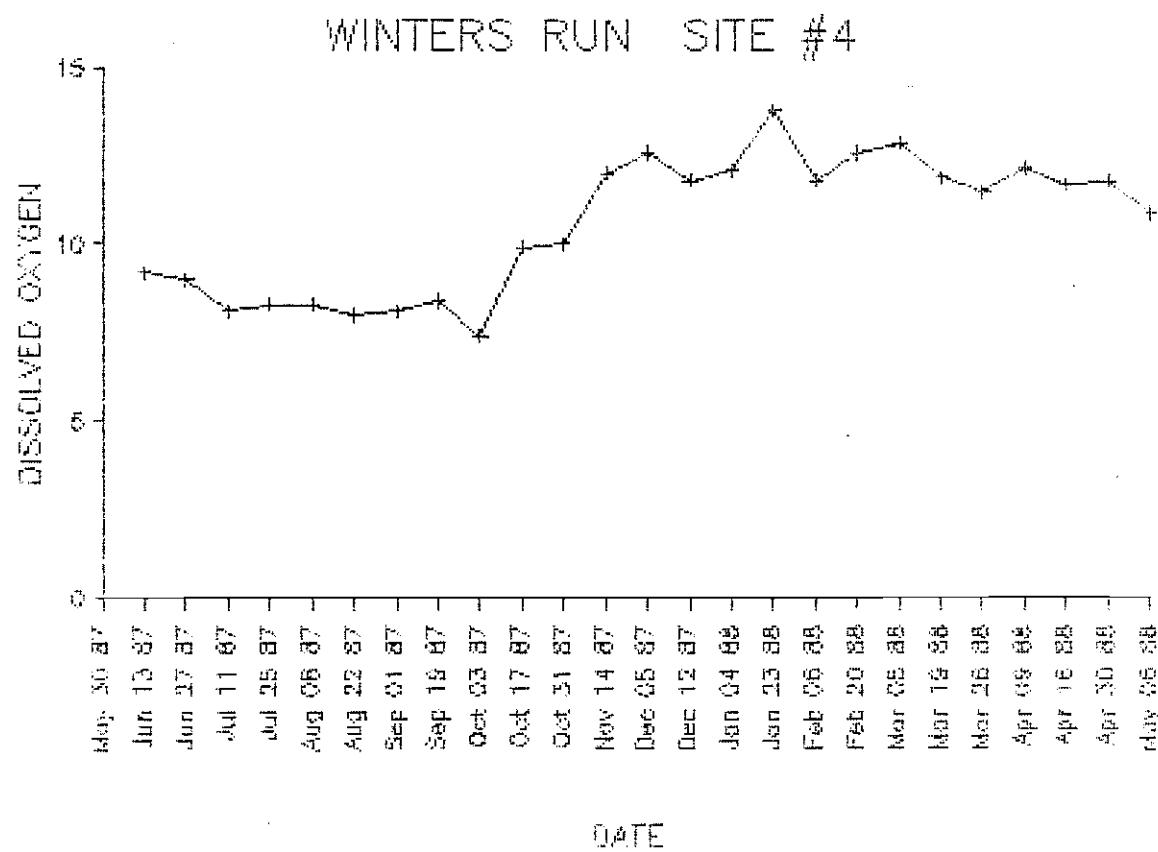
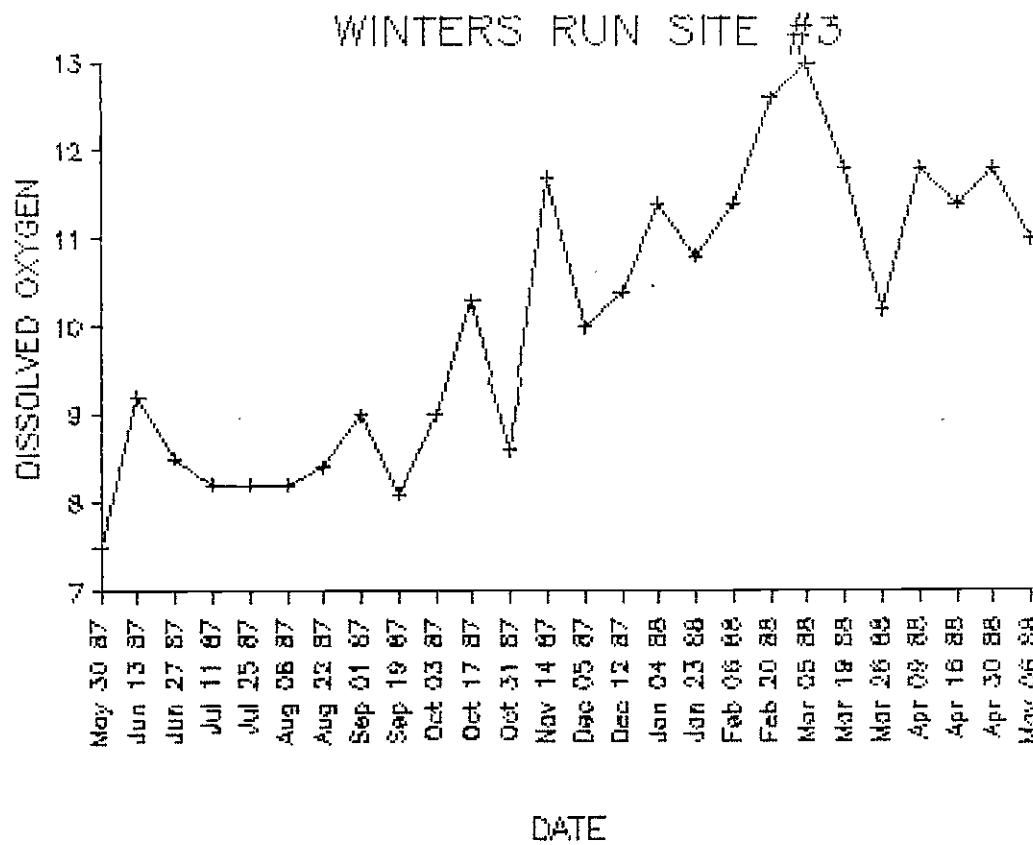




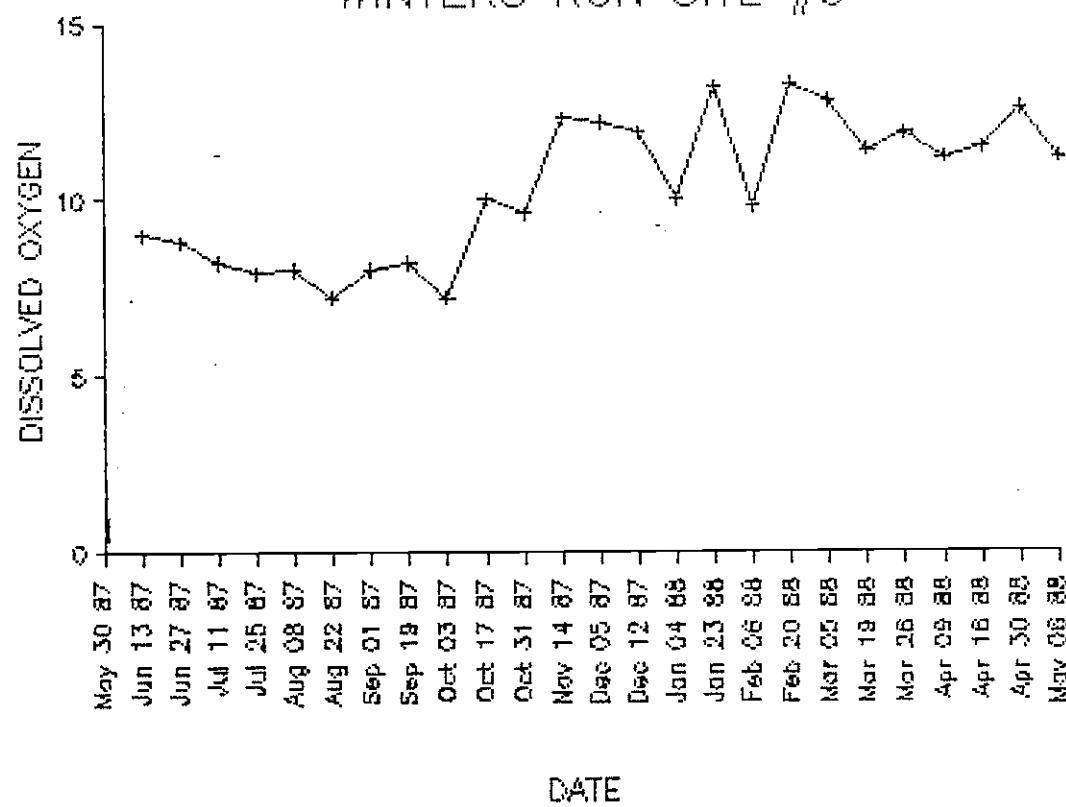
YEARLY AVERAGES
CRANBERRY



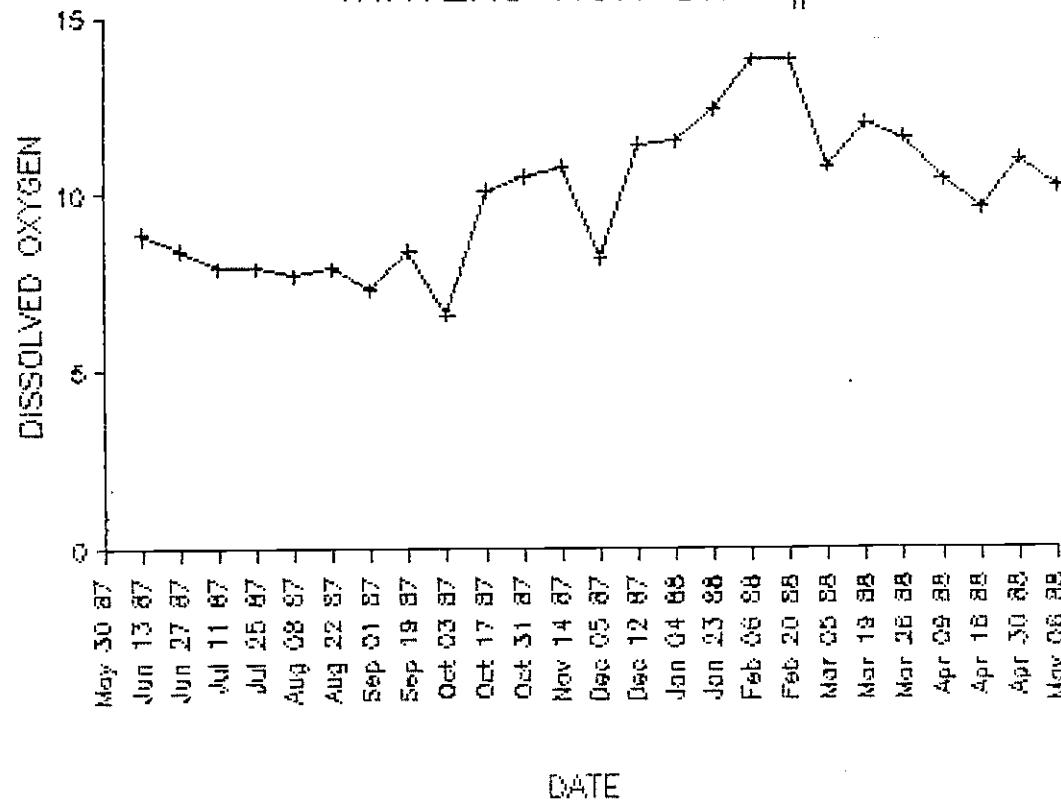


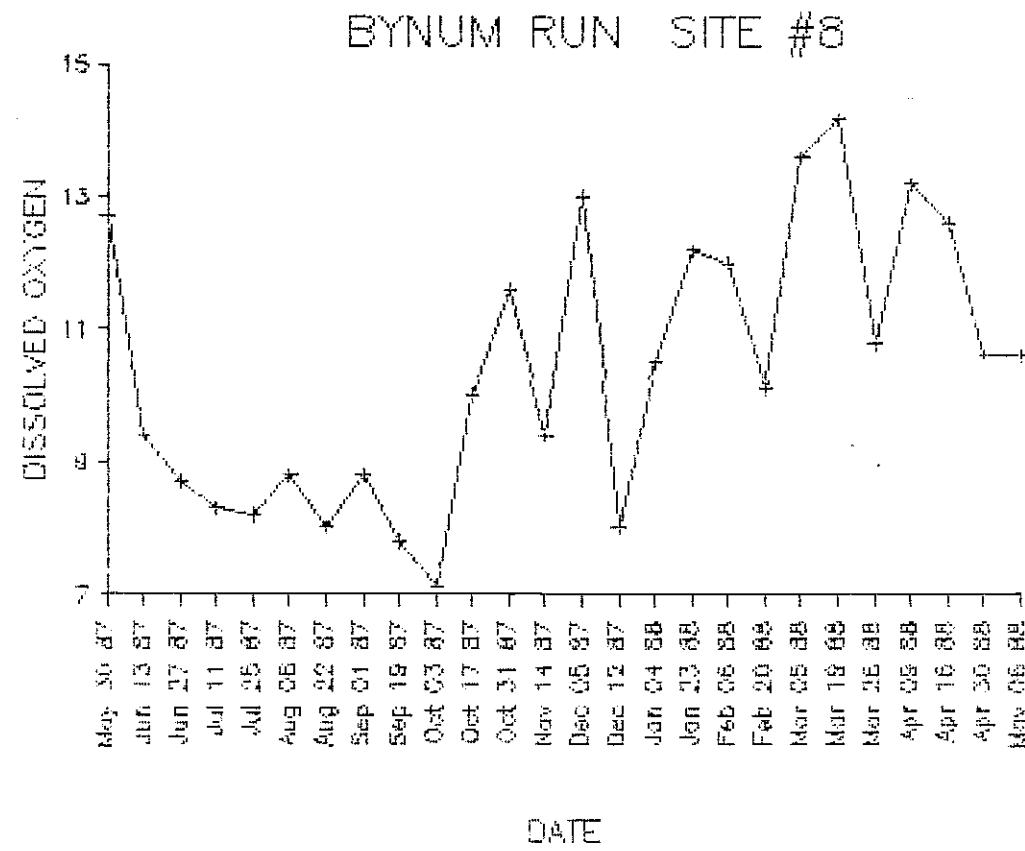
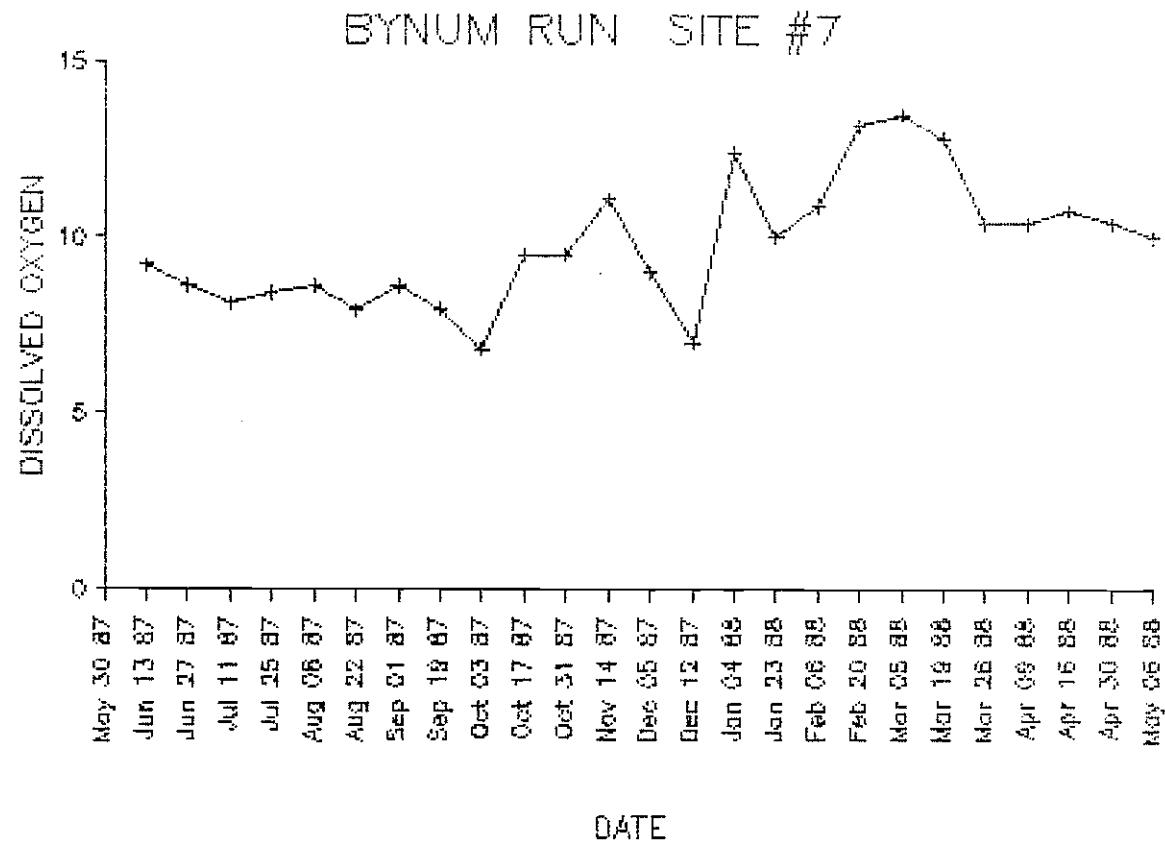


WINTERS RUN SITE #5

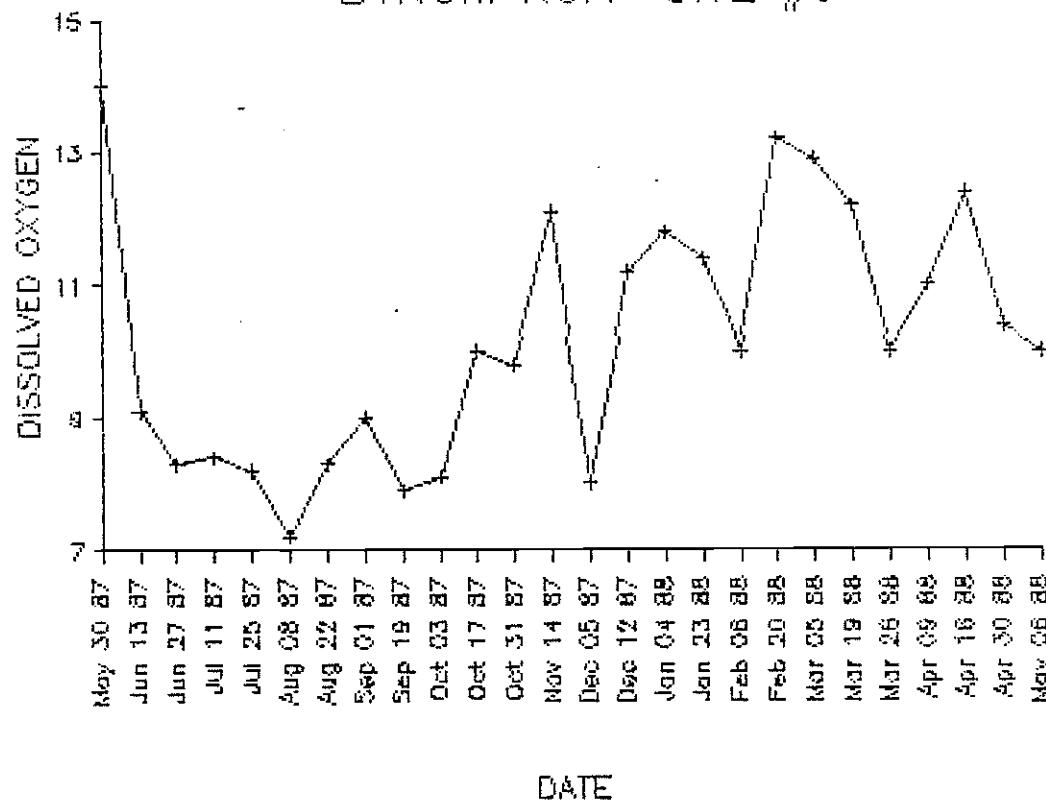


WINTERS RUN SITE #6

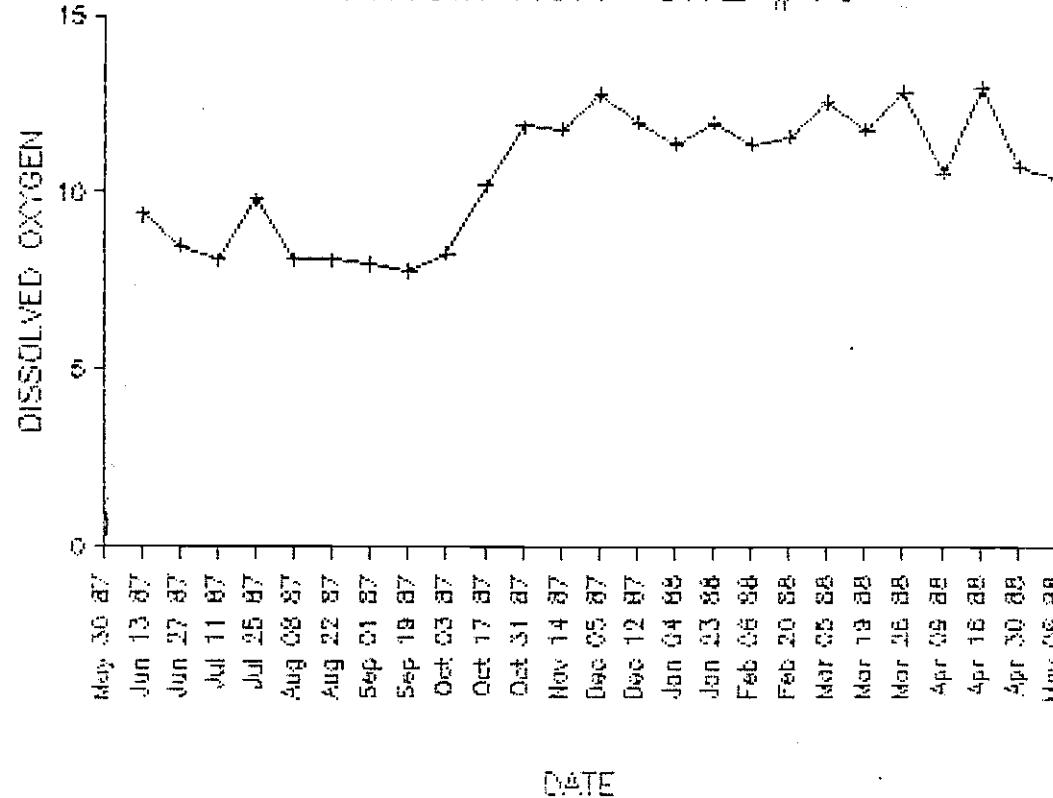




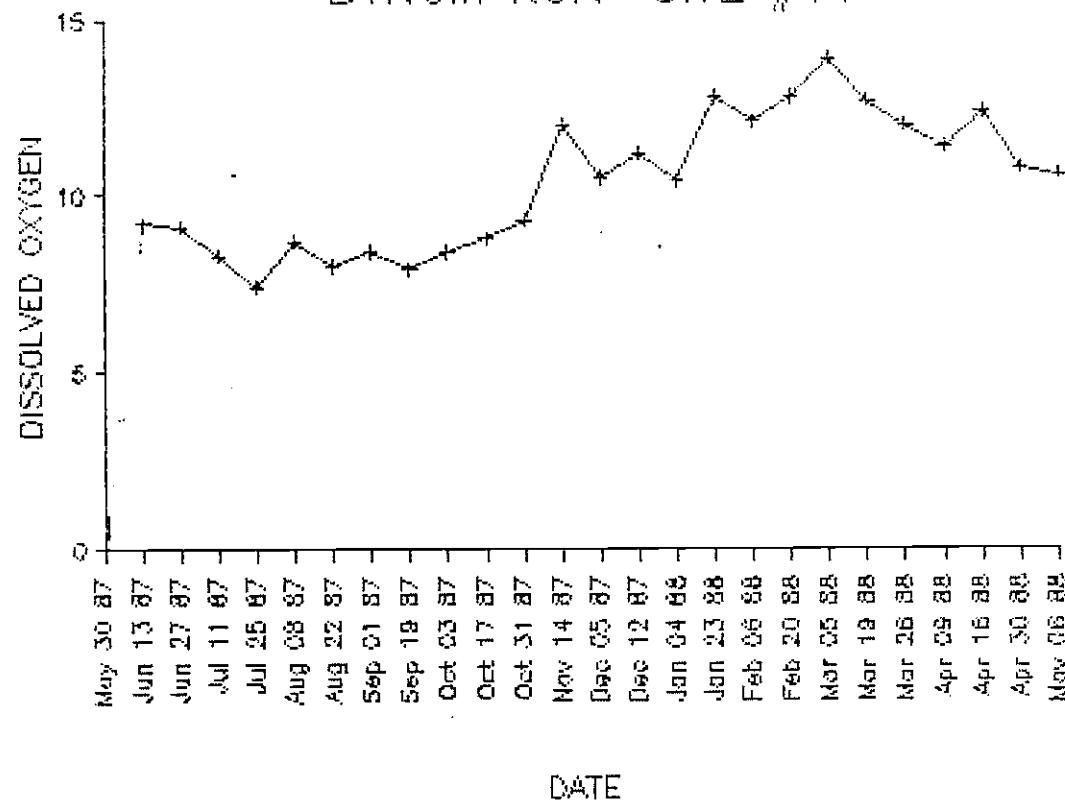
BYNUM RUN SITE #9



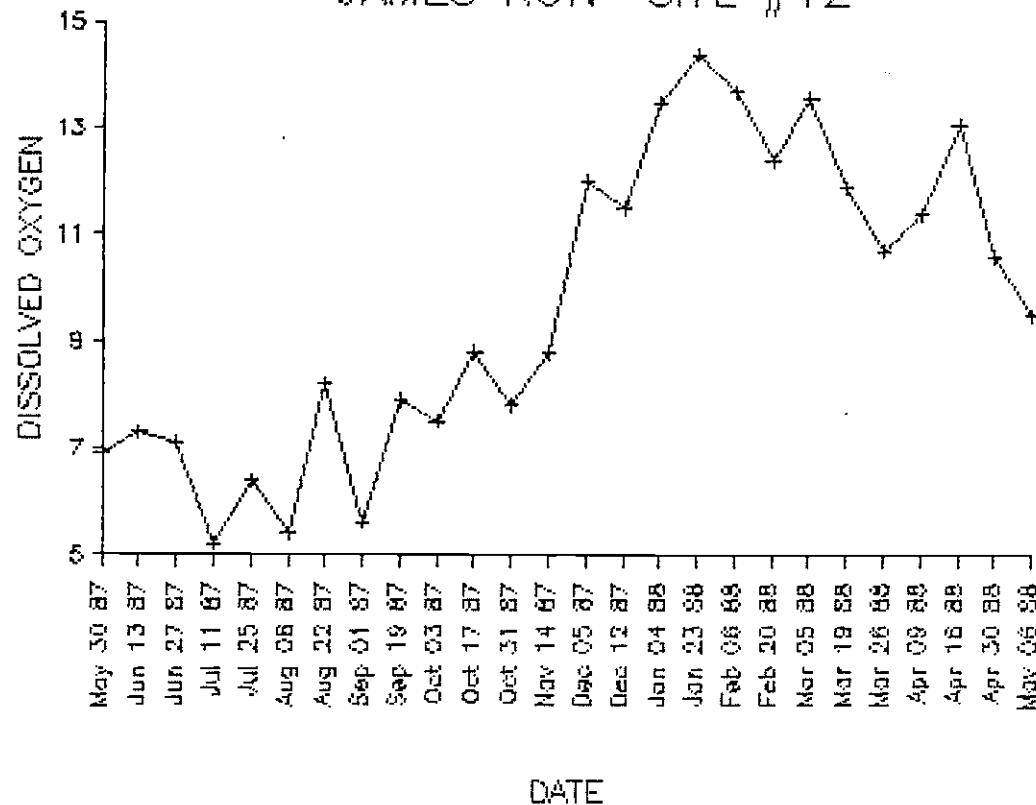
BYNUM RUN SITE #10

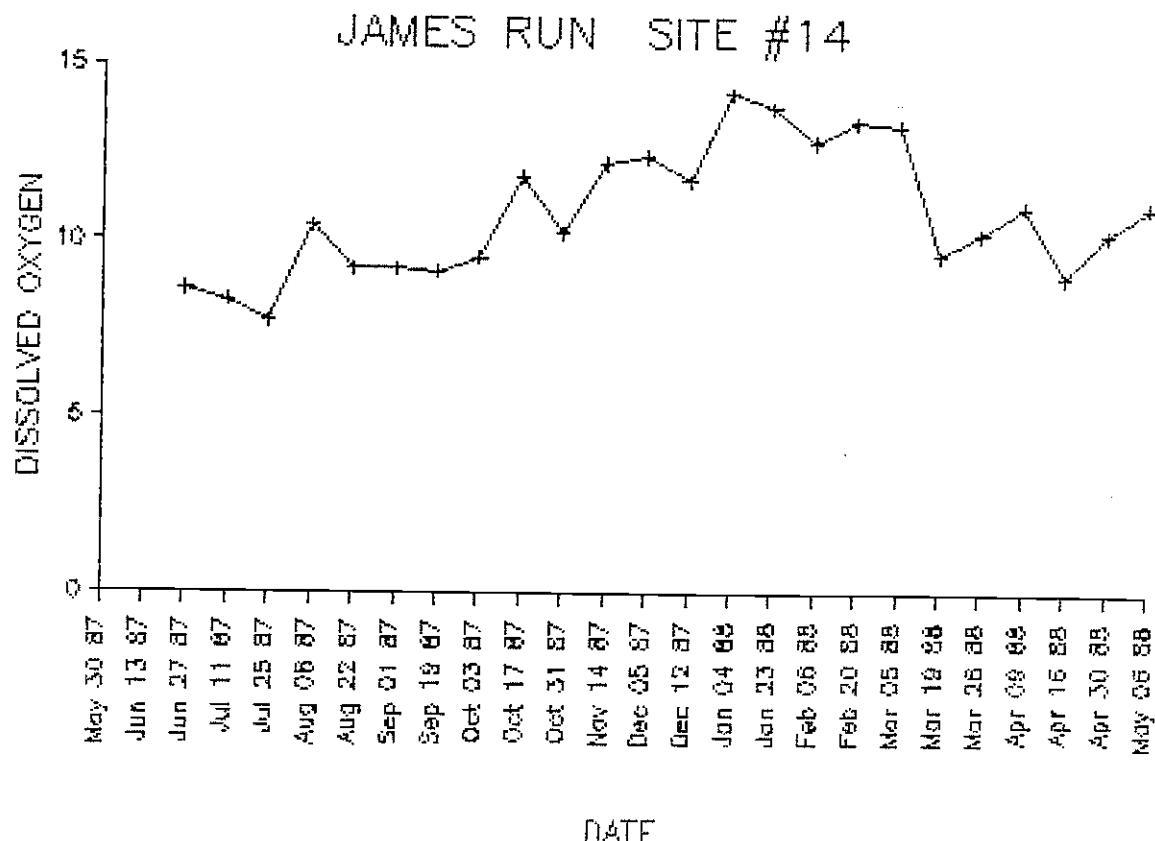
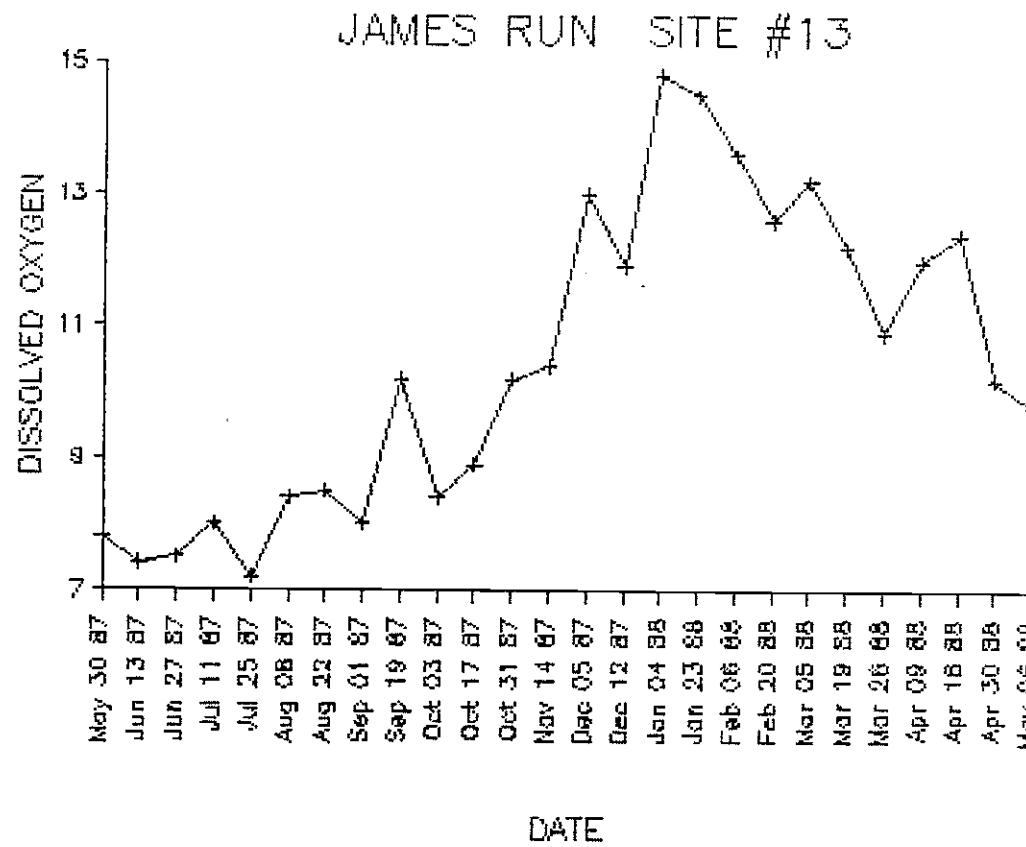


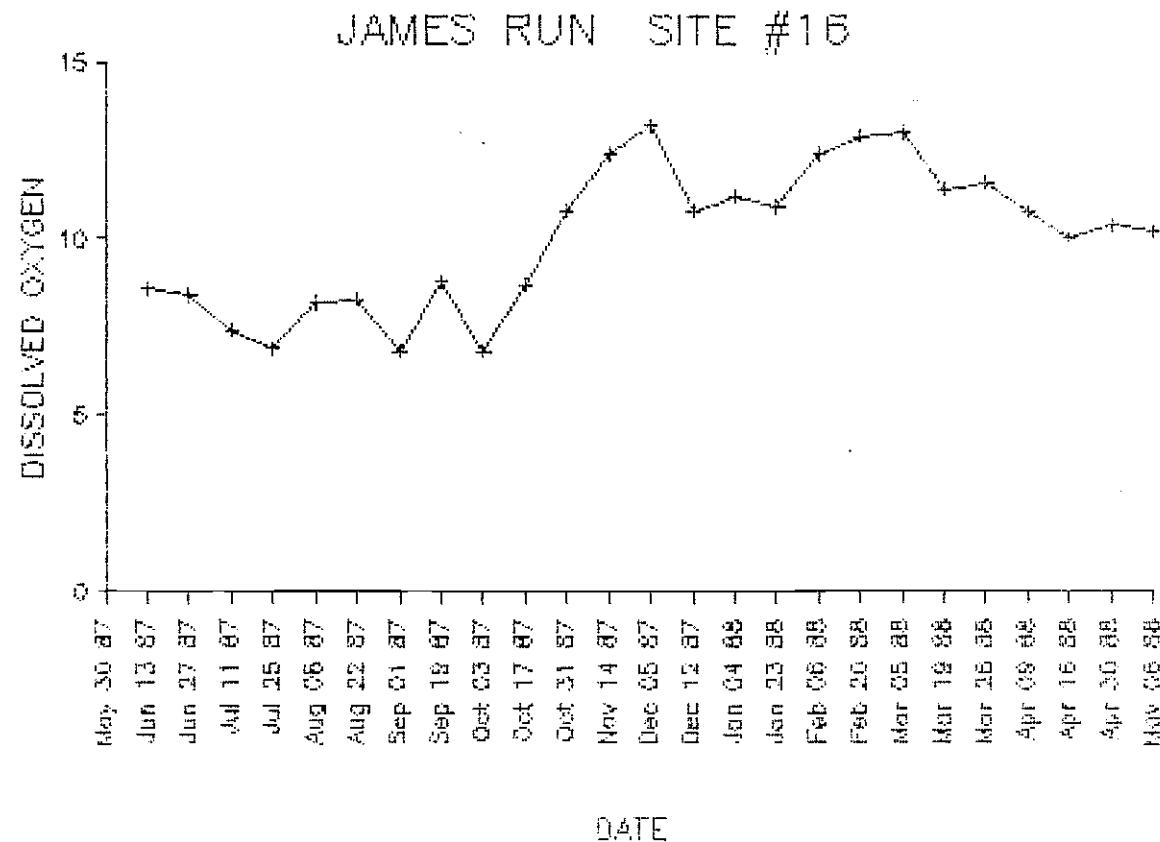
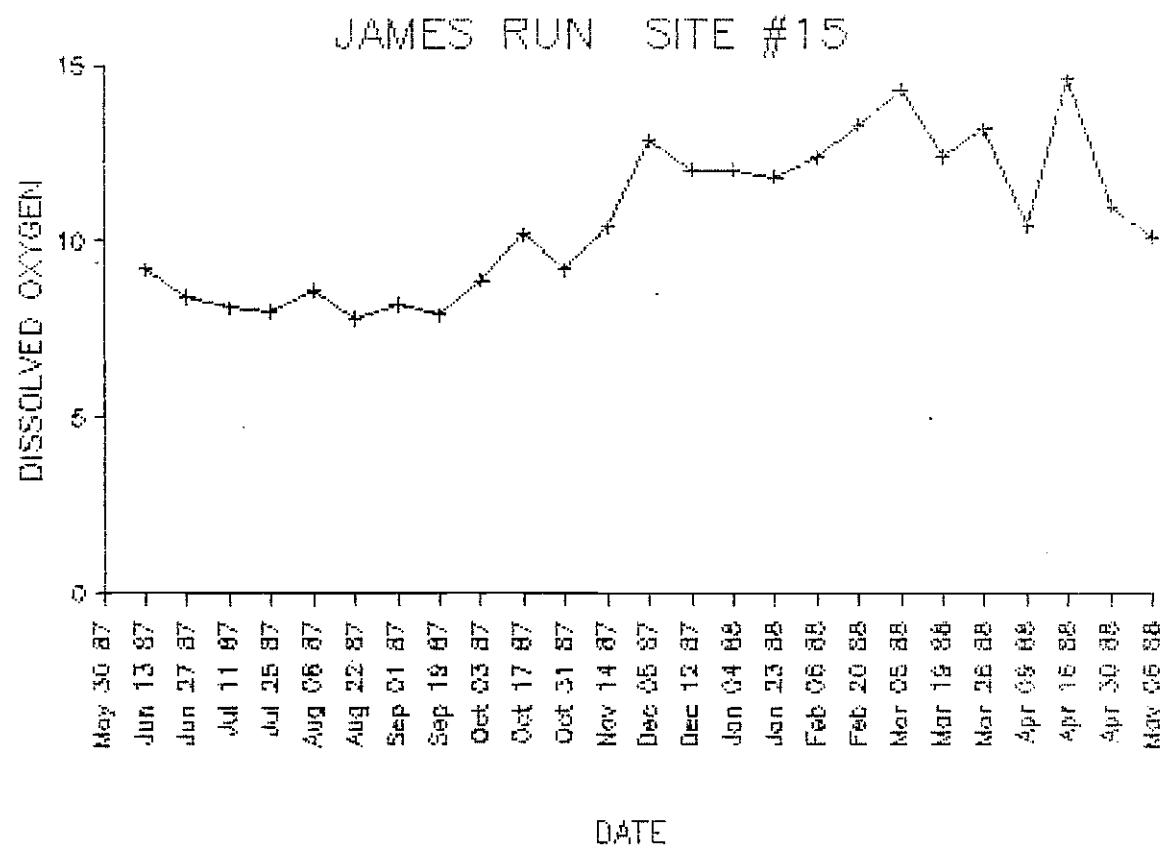
BYNUM RUN SITE #11



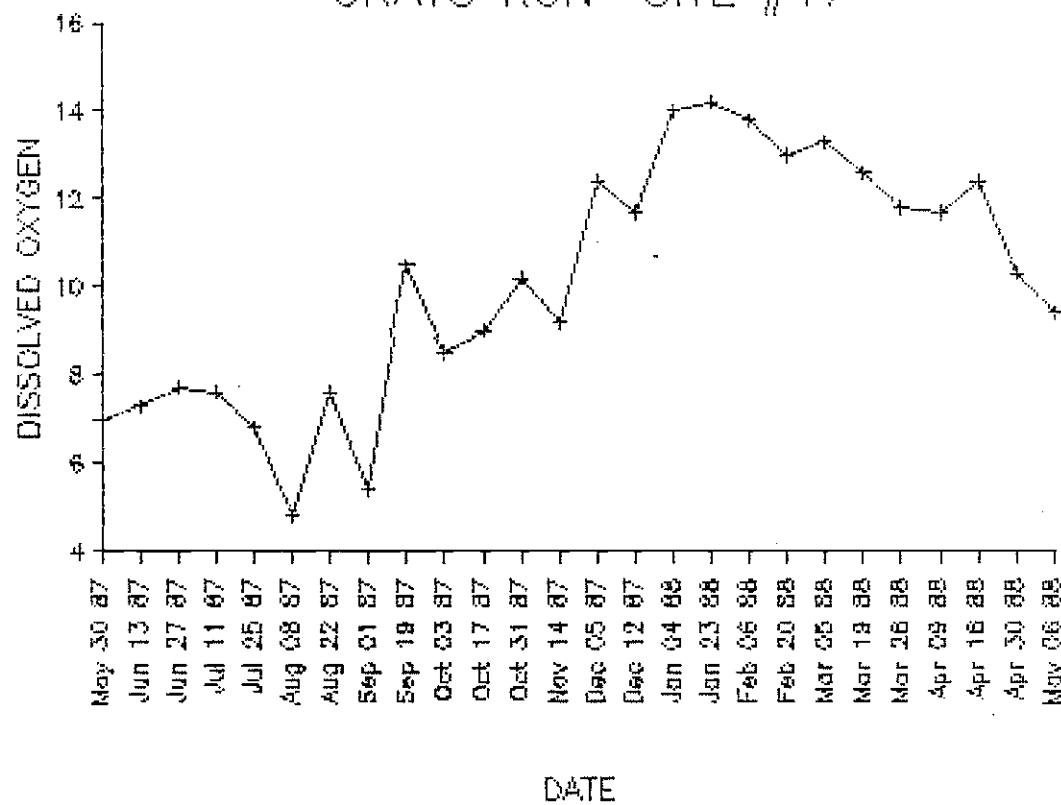
JAMES RUN SITE #12



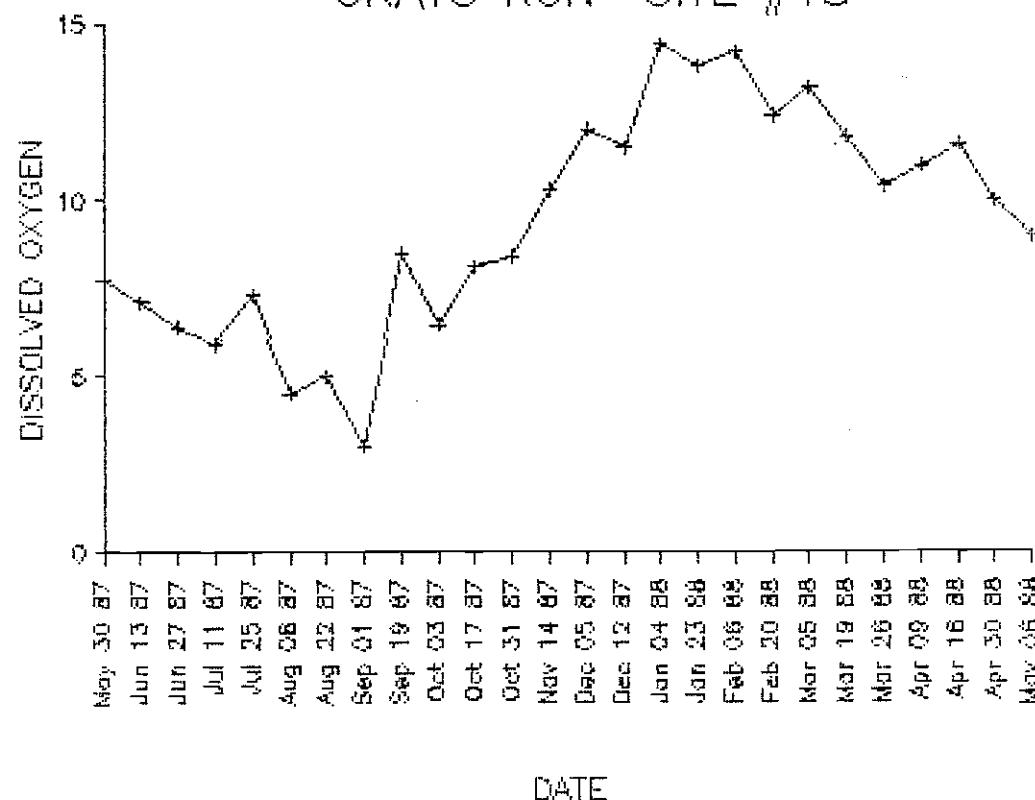


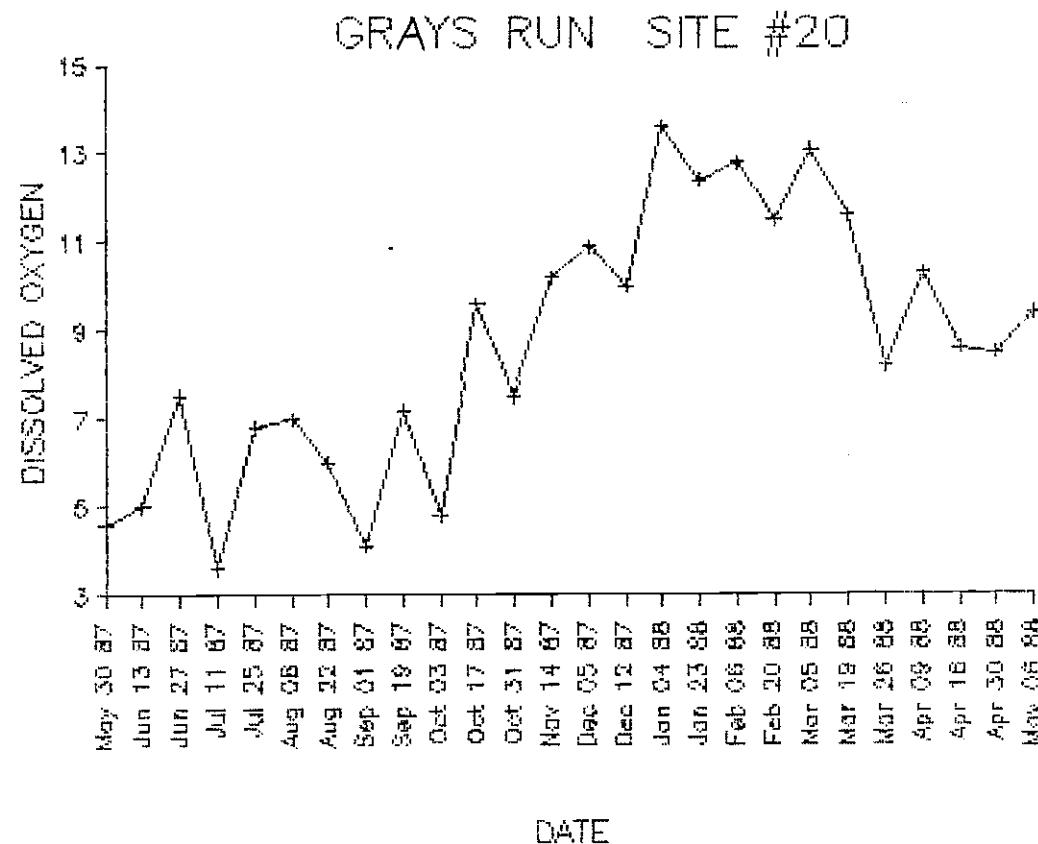
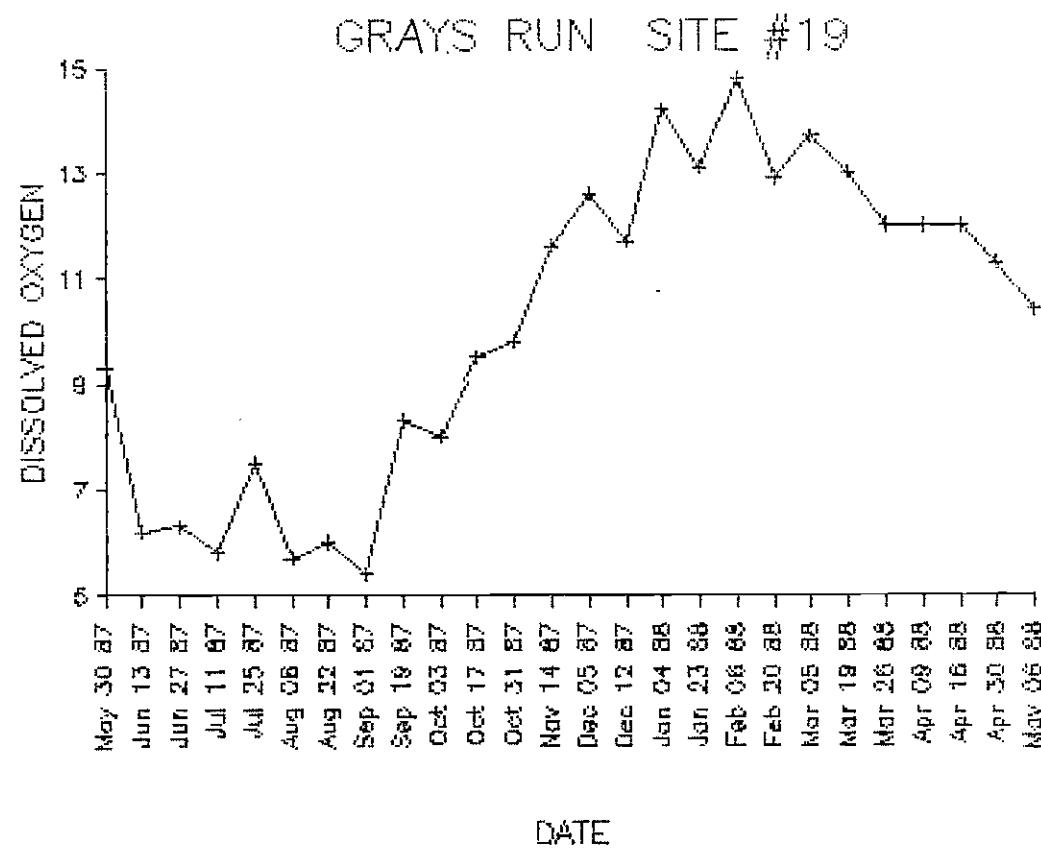


GRAYS RUN SITE #17

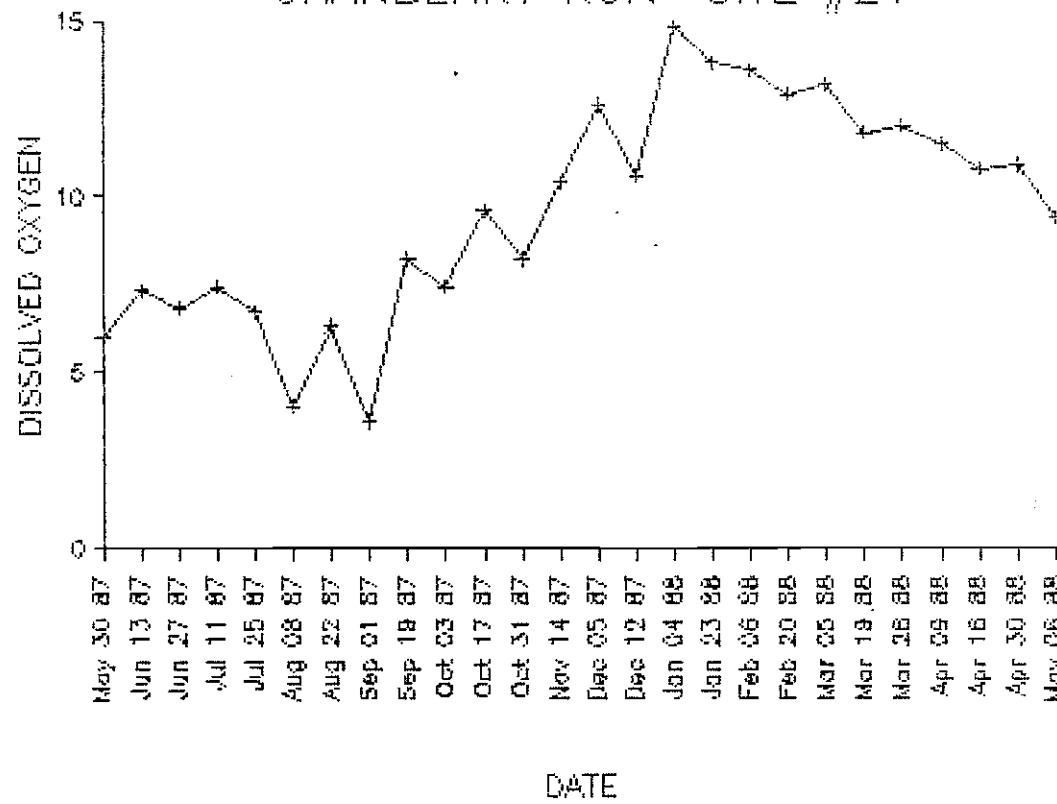


GRAYS RUN SITE #18

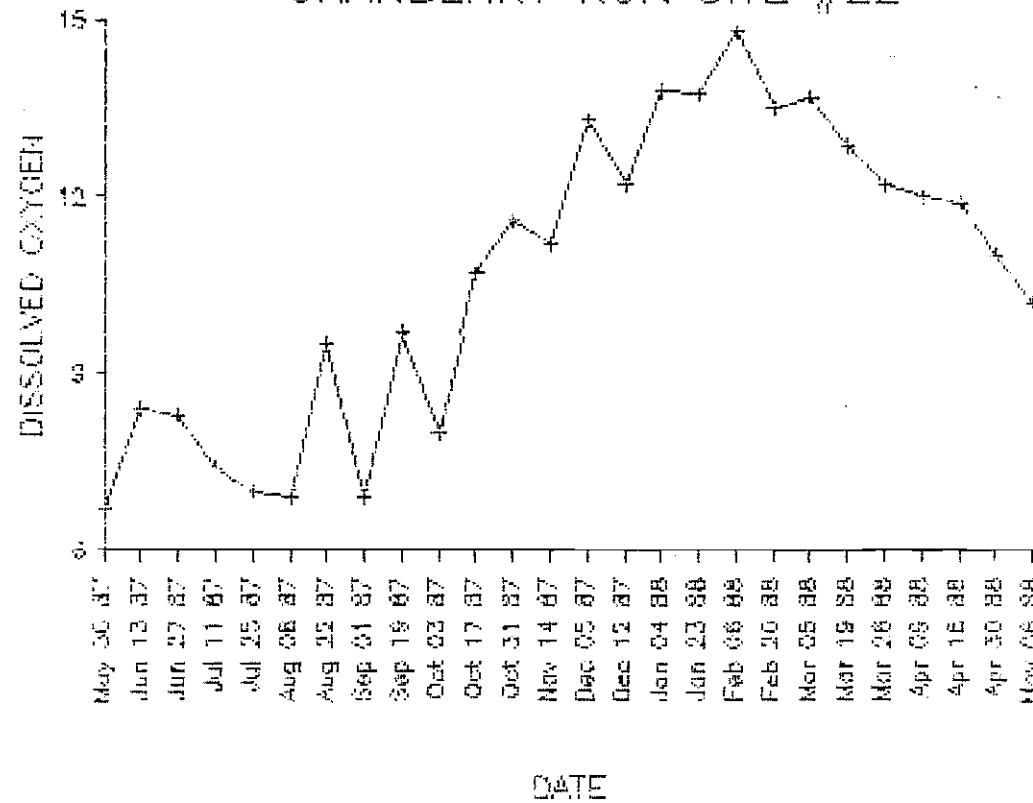




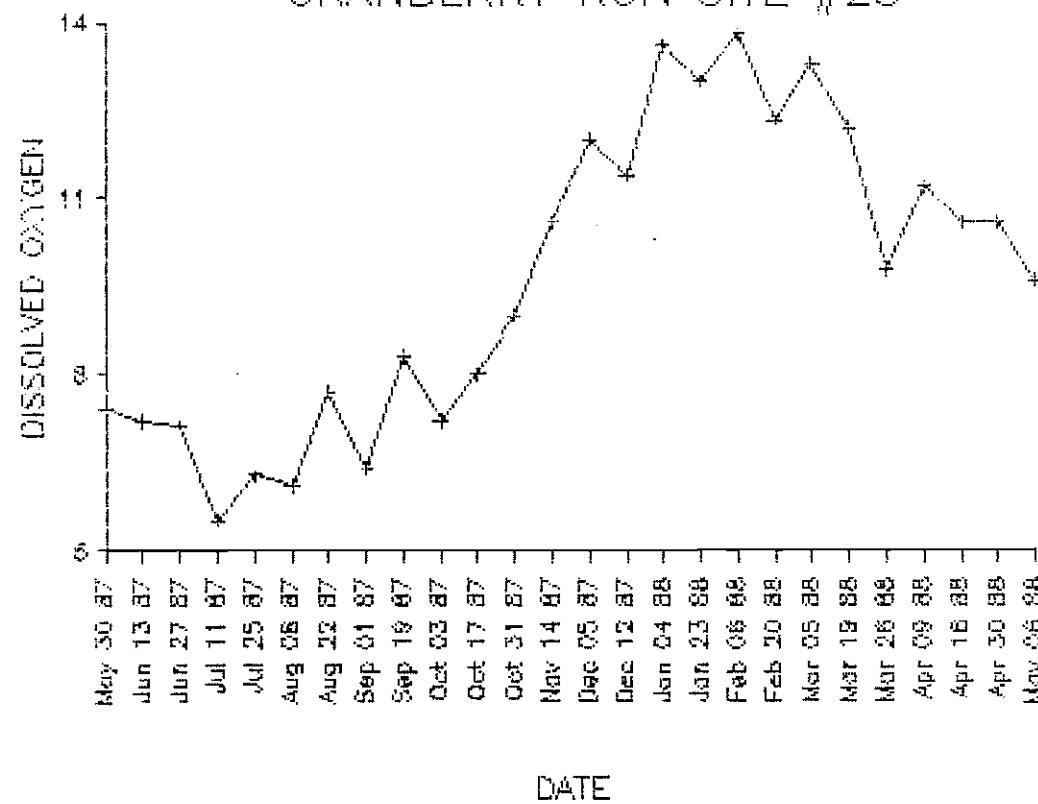
CRANBERRY RUN SITE #21



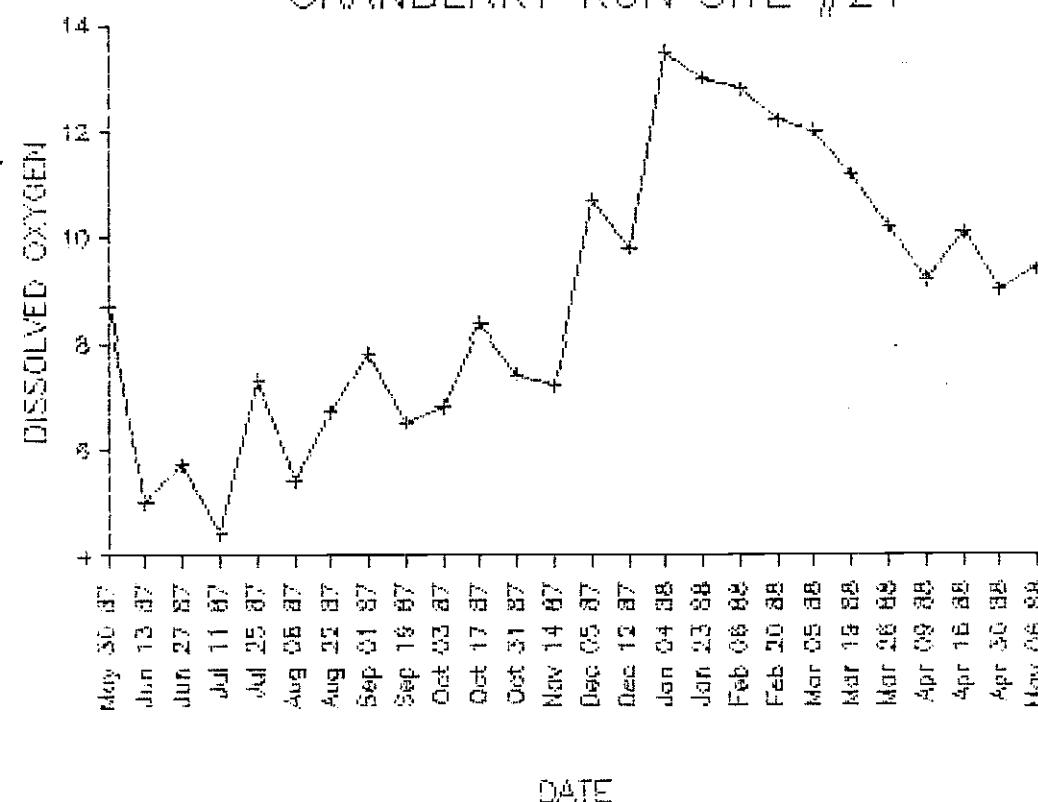
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23

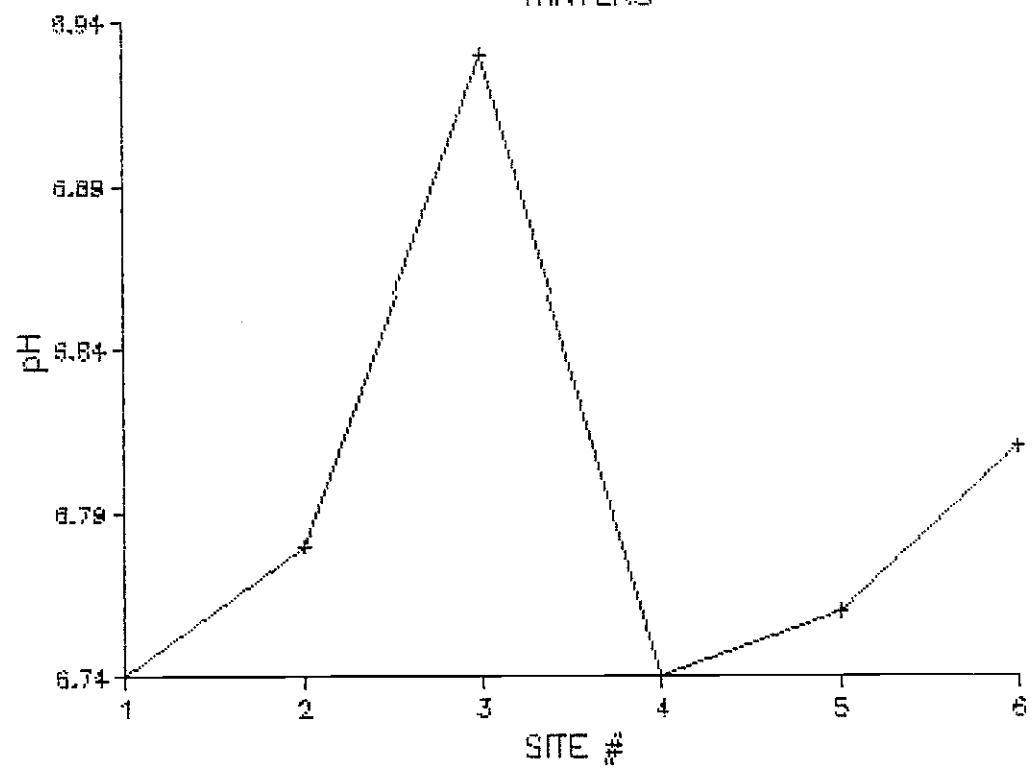


CRANBERRY RUN SITE #24

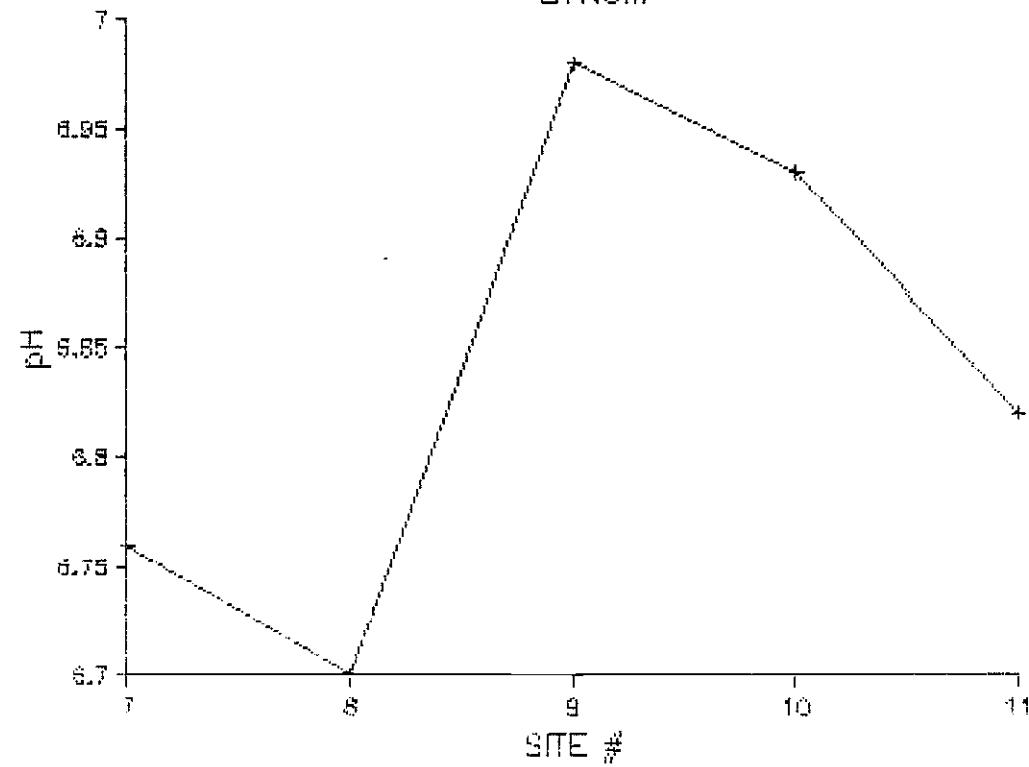


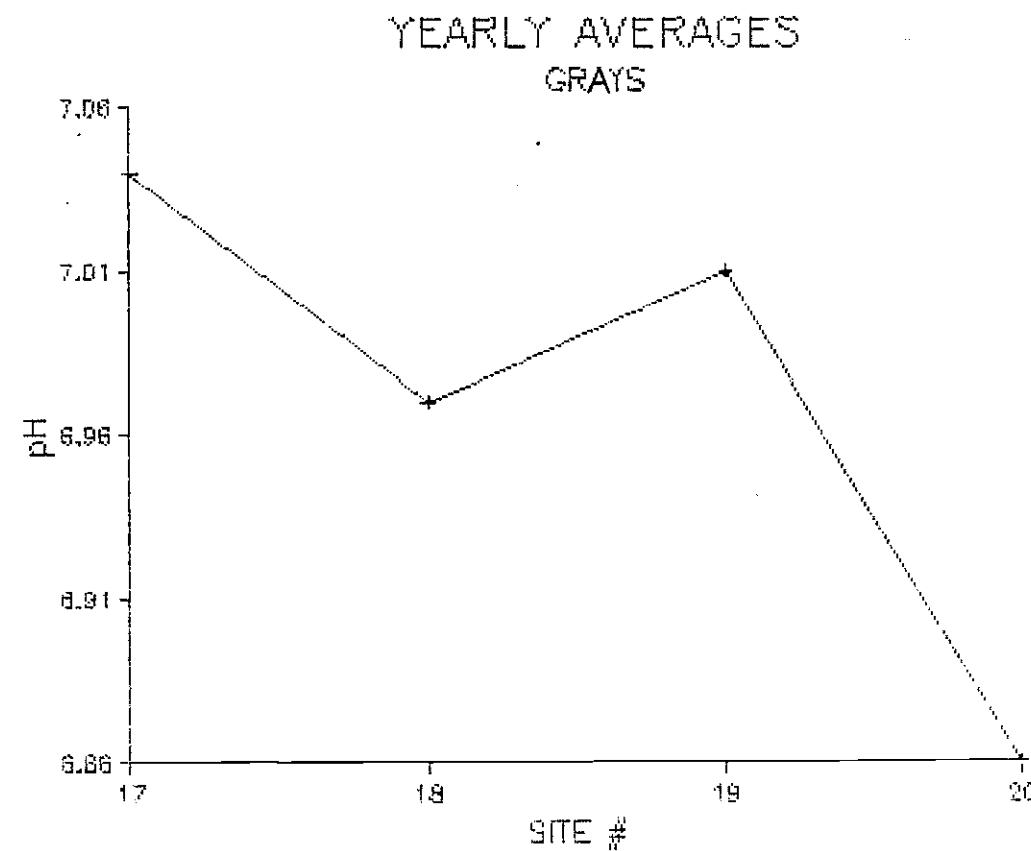
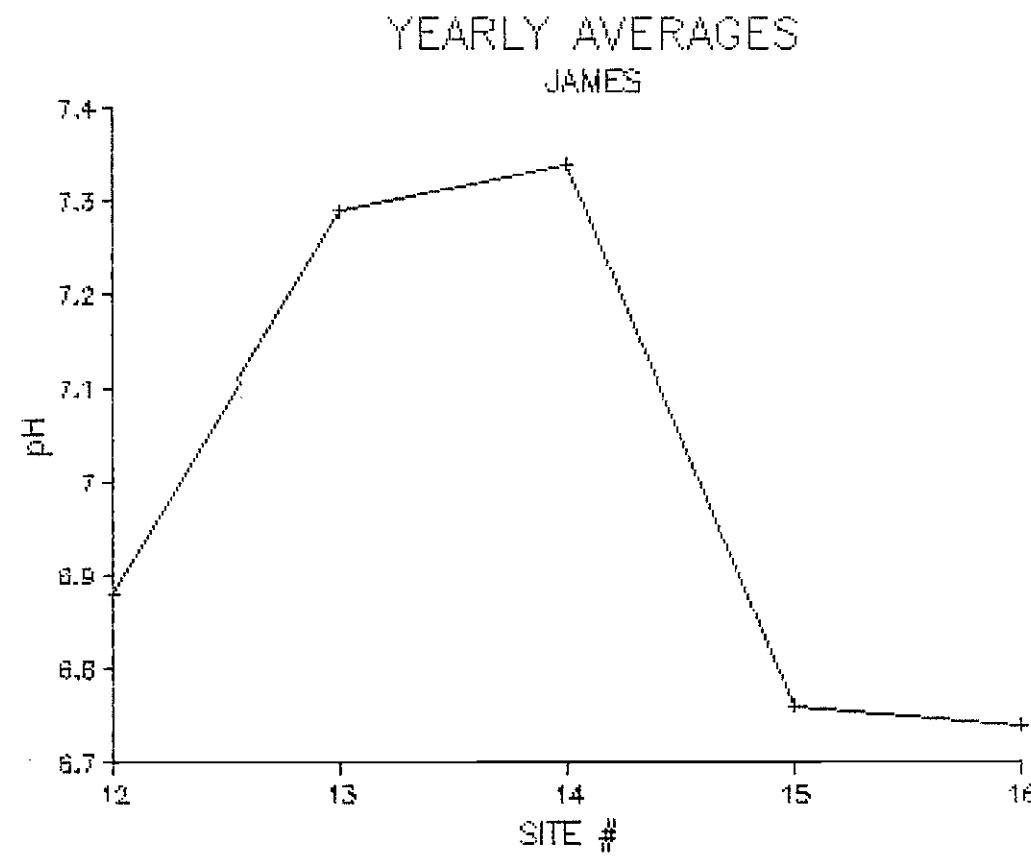
18

YEARLY AVERAGES
WINTERS

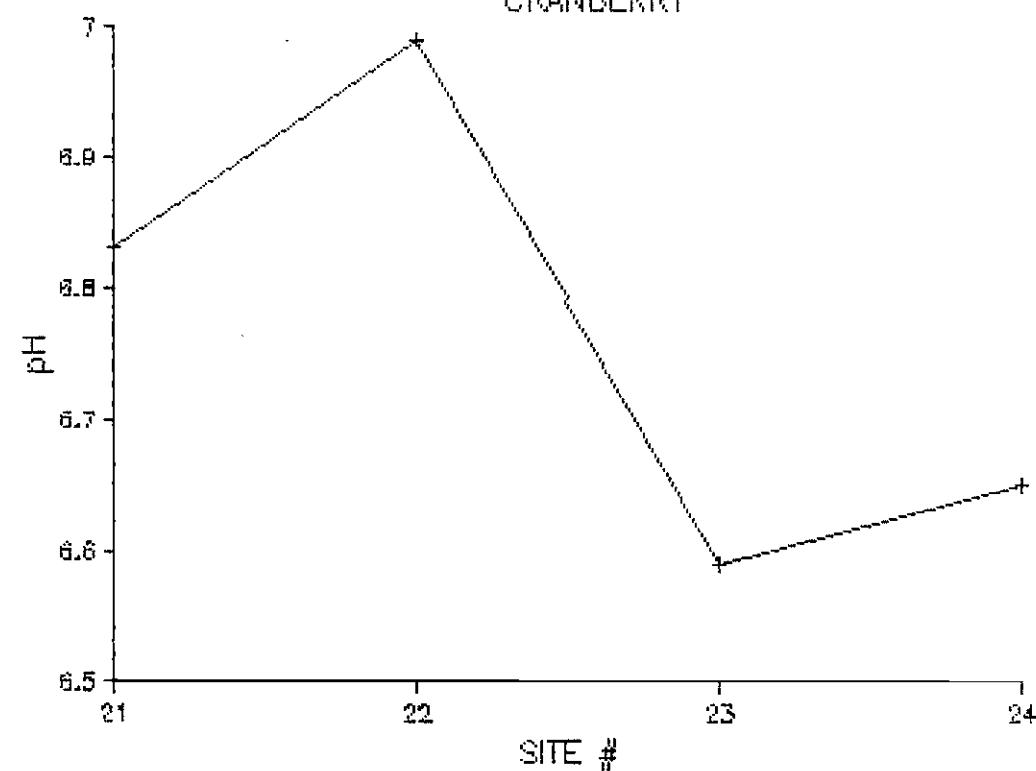


YEARLY AVERAGES
BYNUM

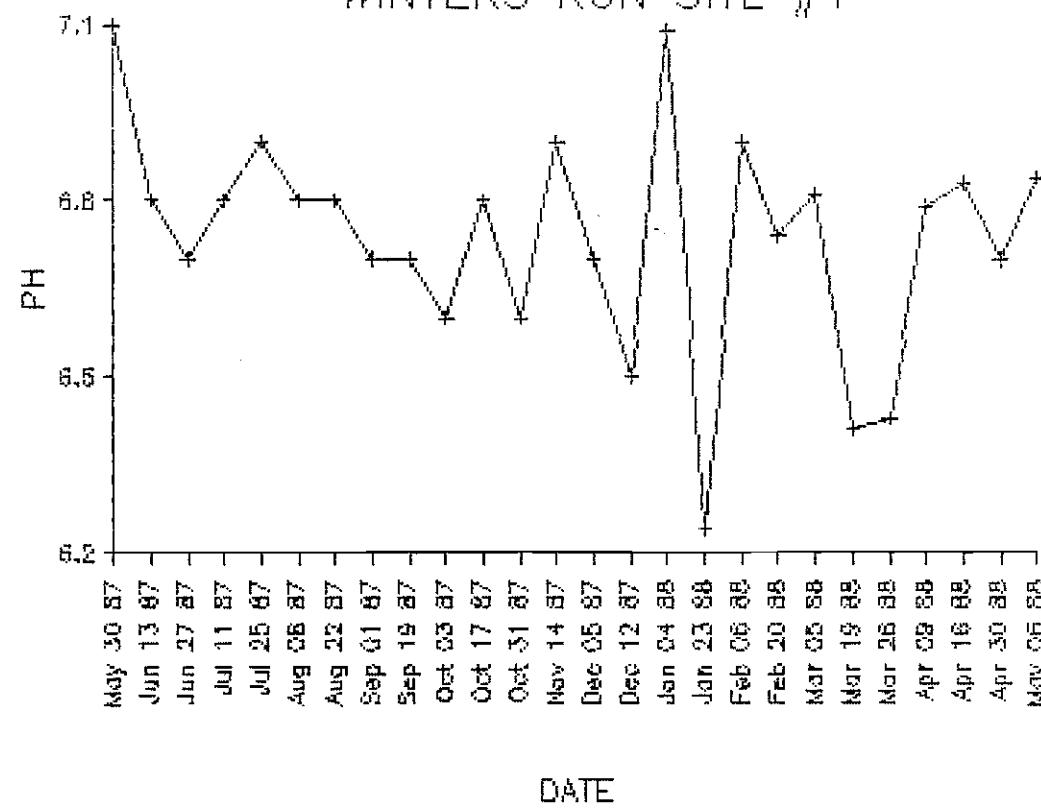




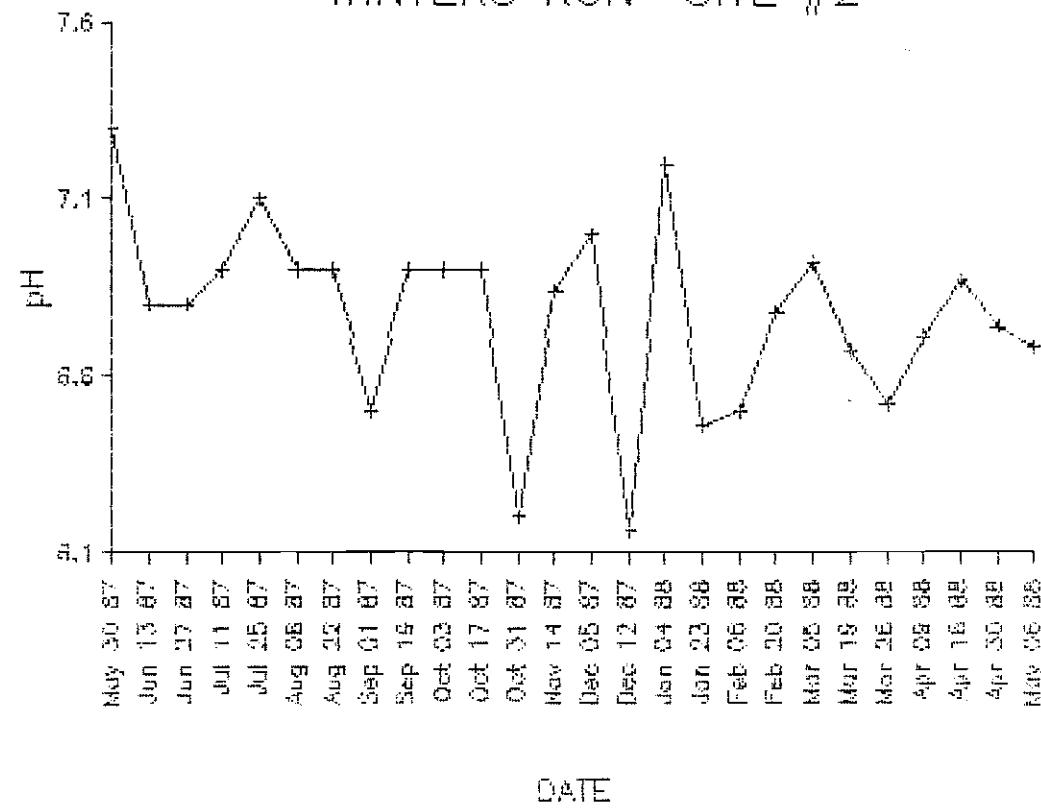
YEARLY AVERAGES
CRANBERRY



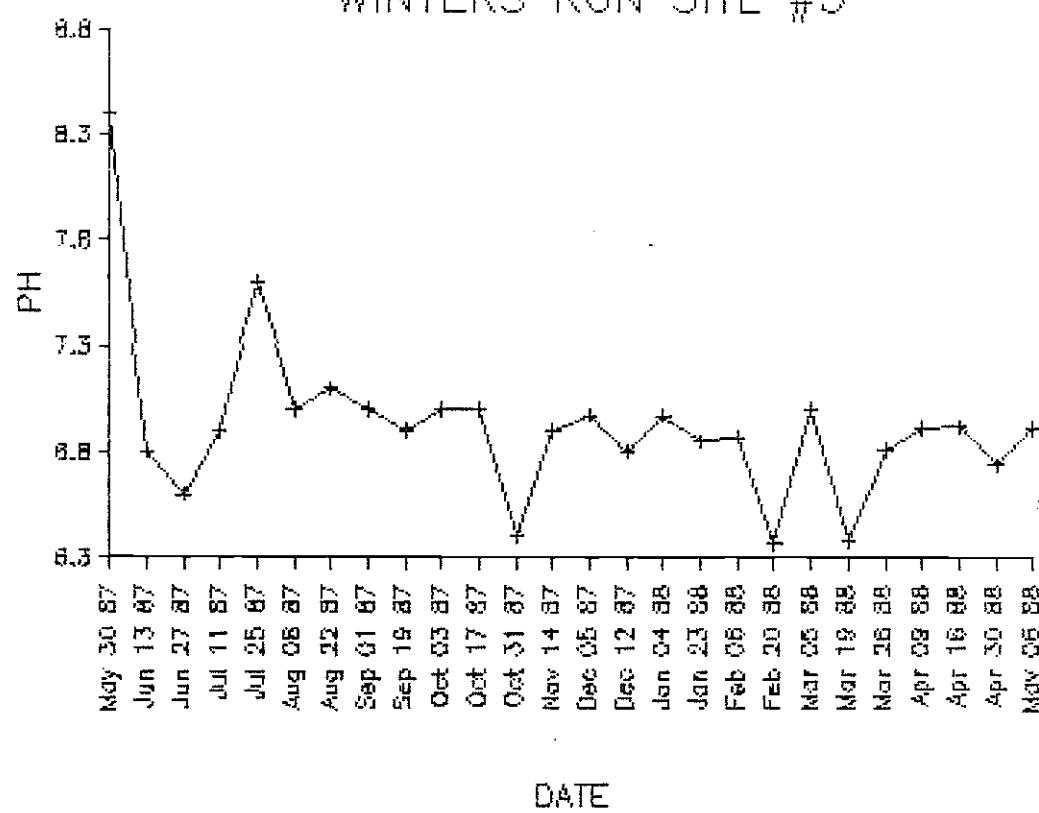
WINTERS RUN SITE #1



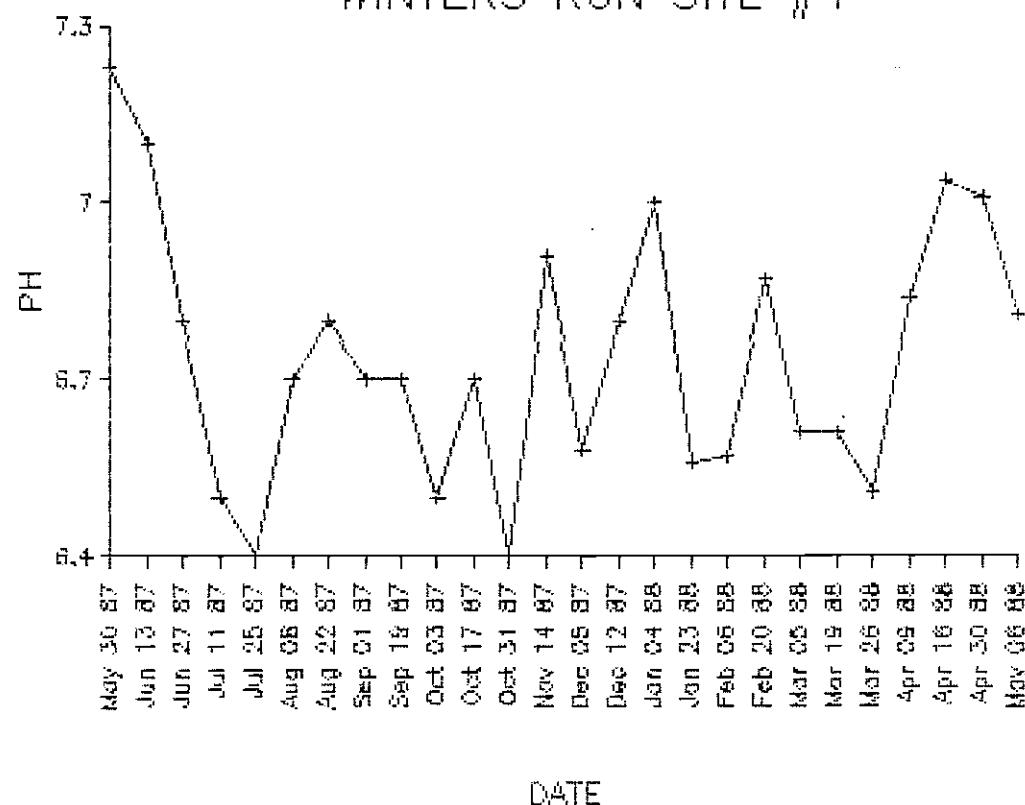
WINTERS RUN SITE #2



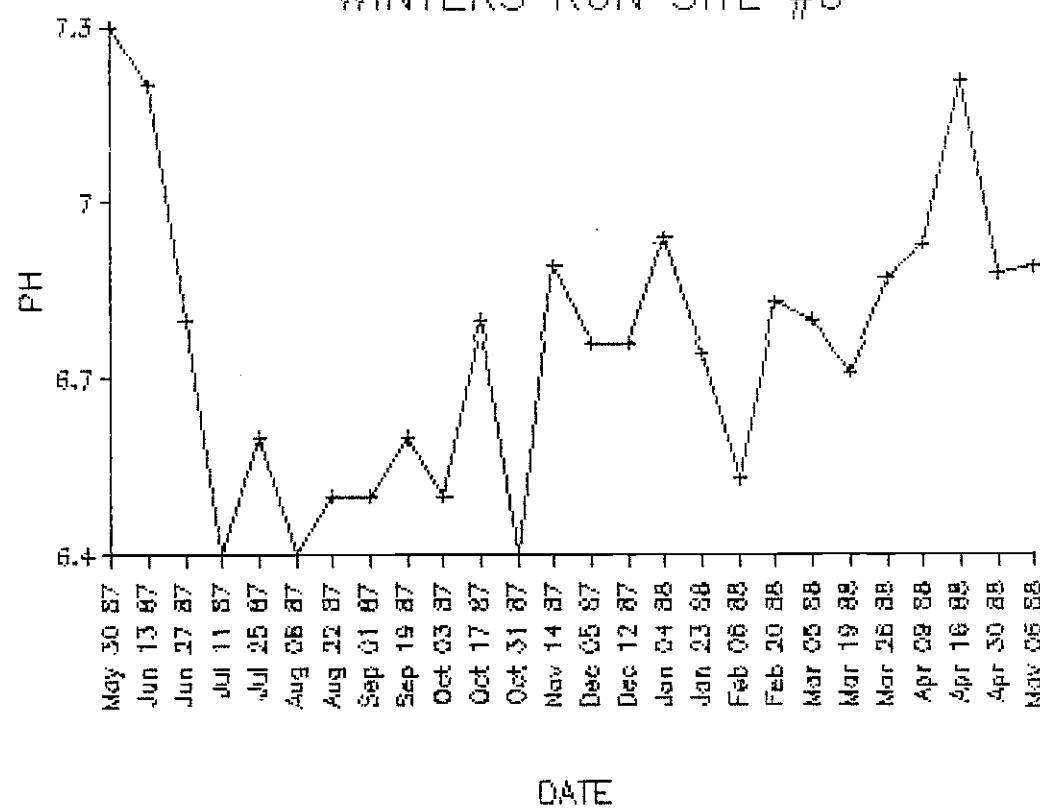
WINTERS RUN SITE #3



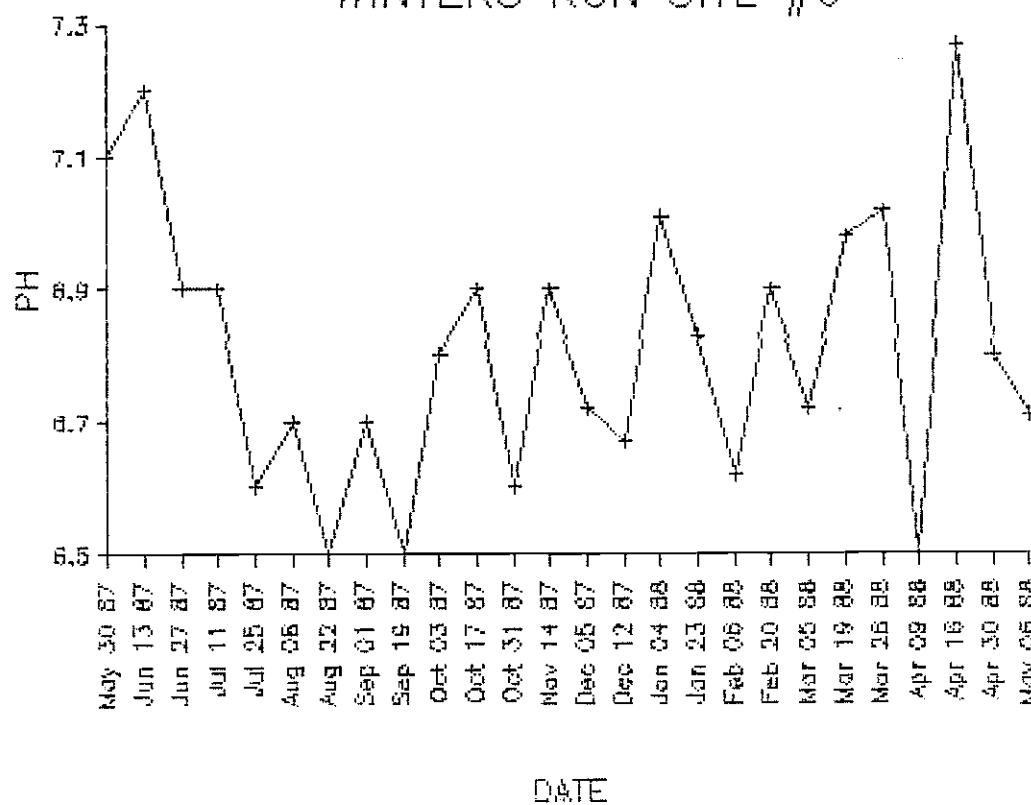
WINTERS RUN SITE #4



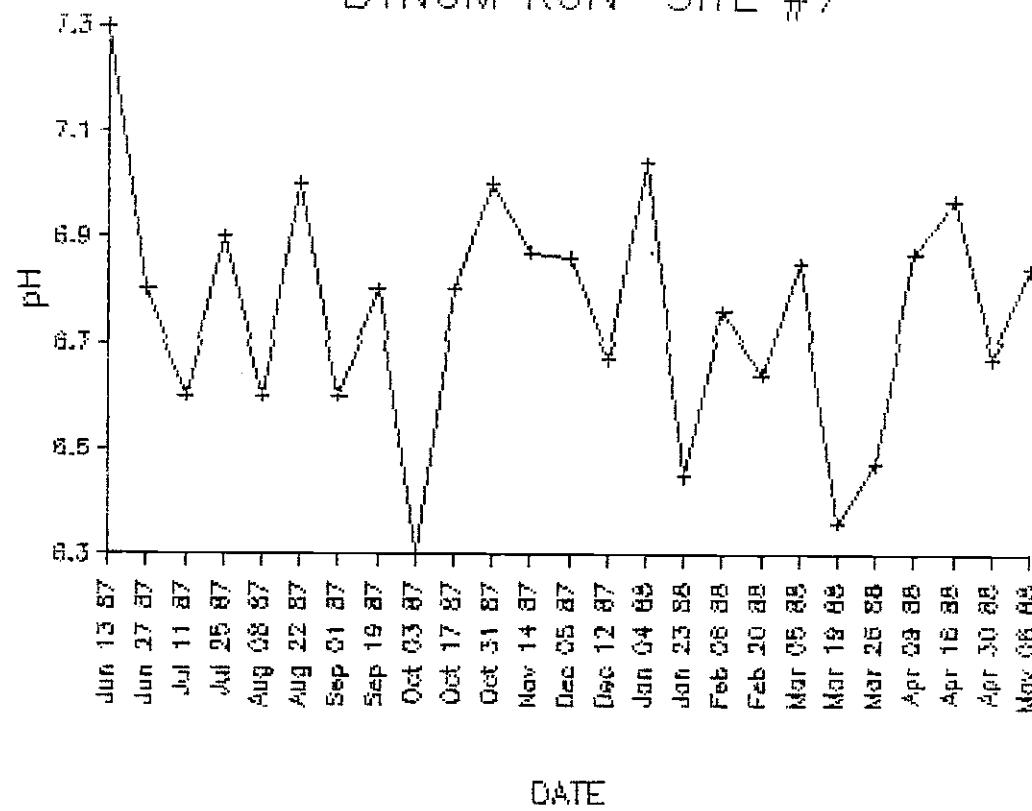
WINTERS RUN SITE #5



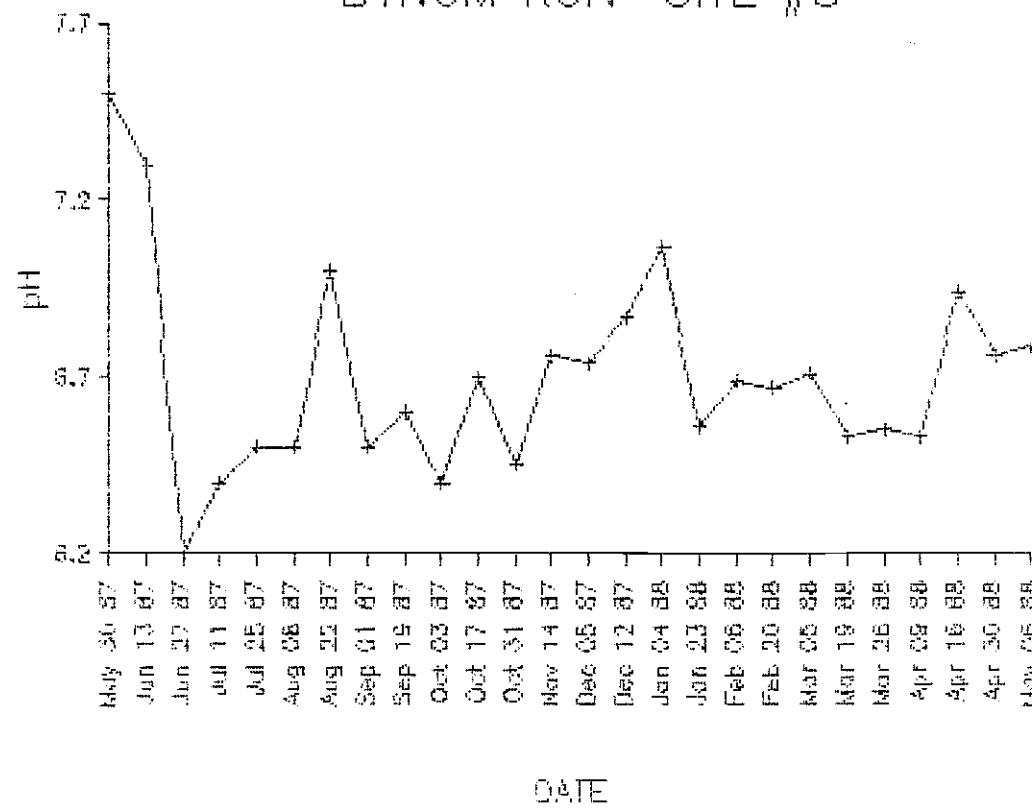
WINTERS RUN SITE #6

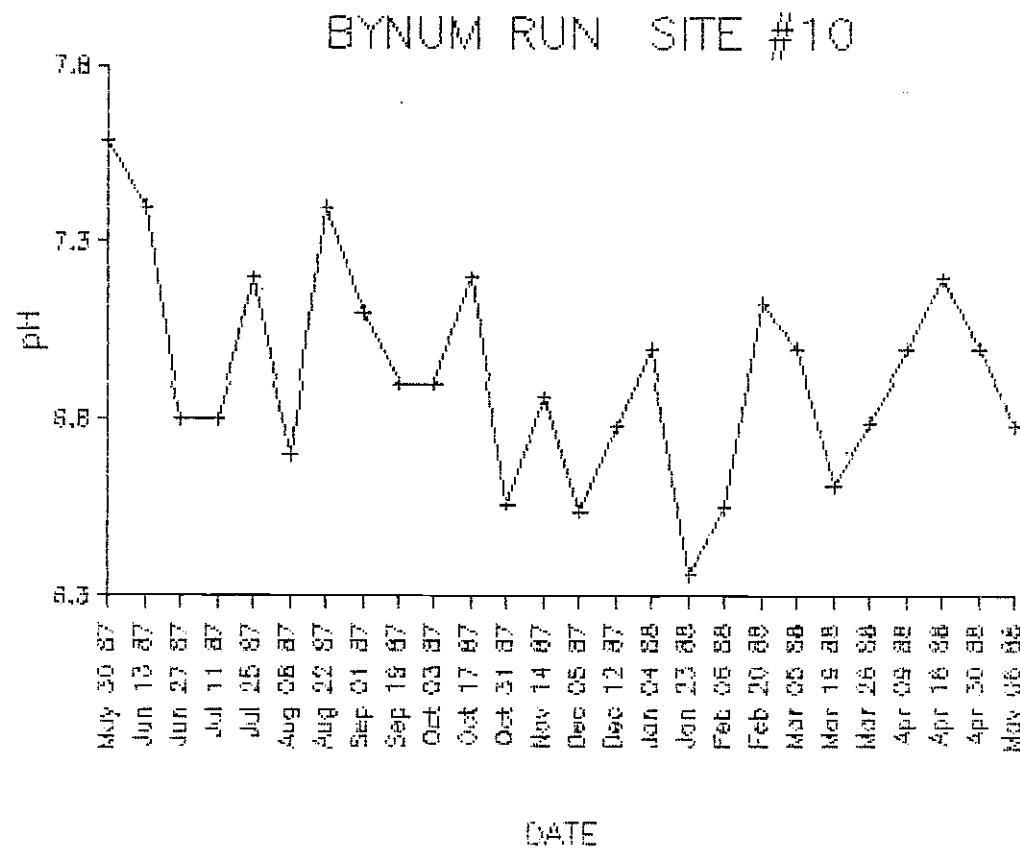
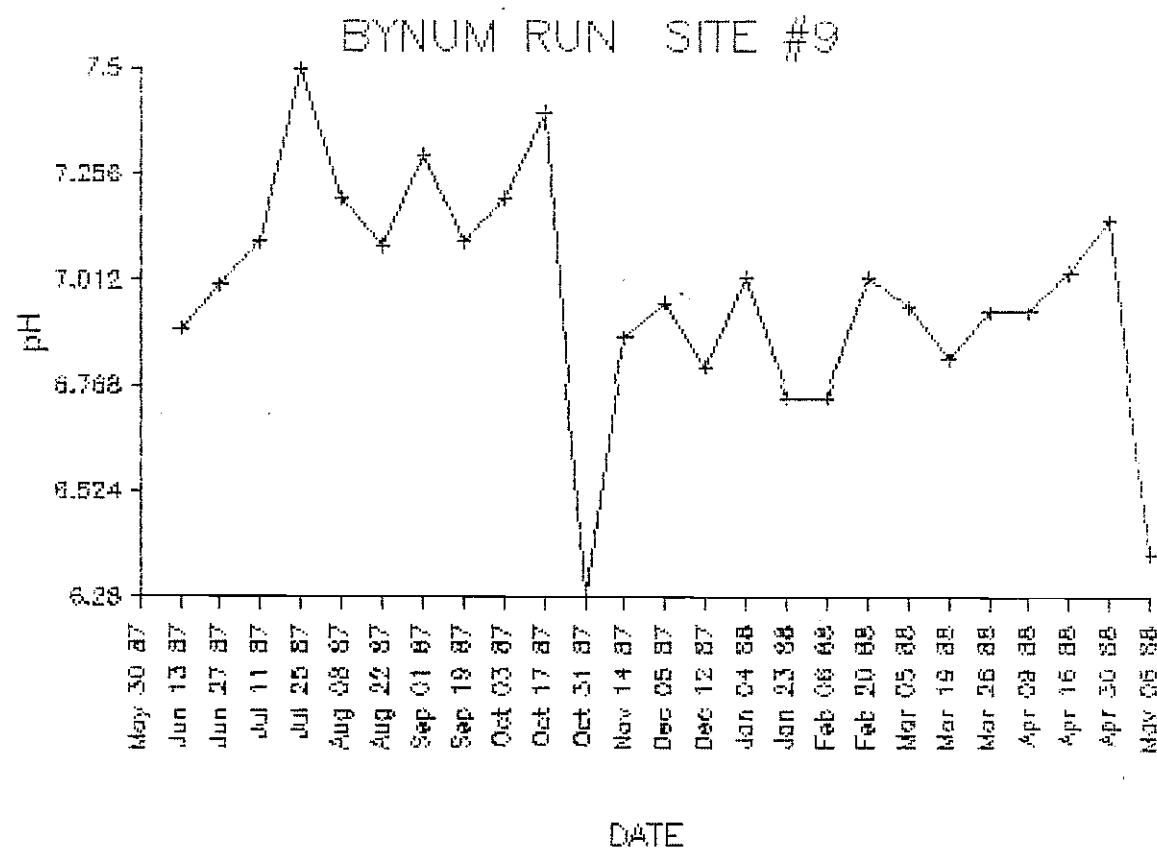


BYNUM RUN SITE #7

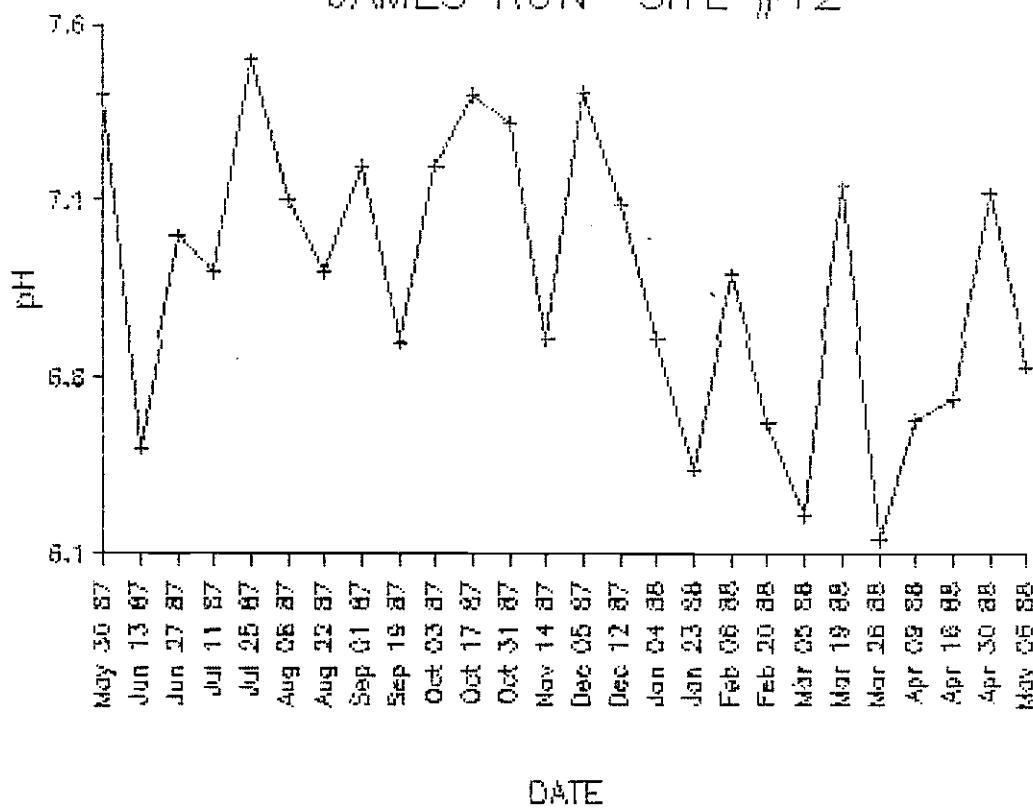


BYNUM RUN SITE #8

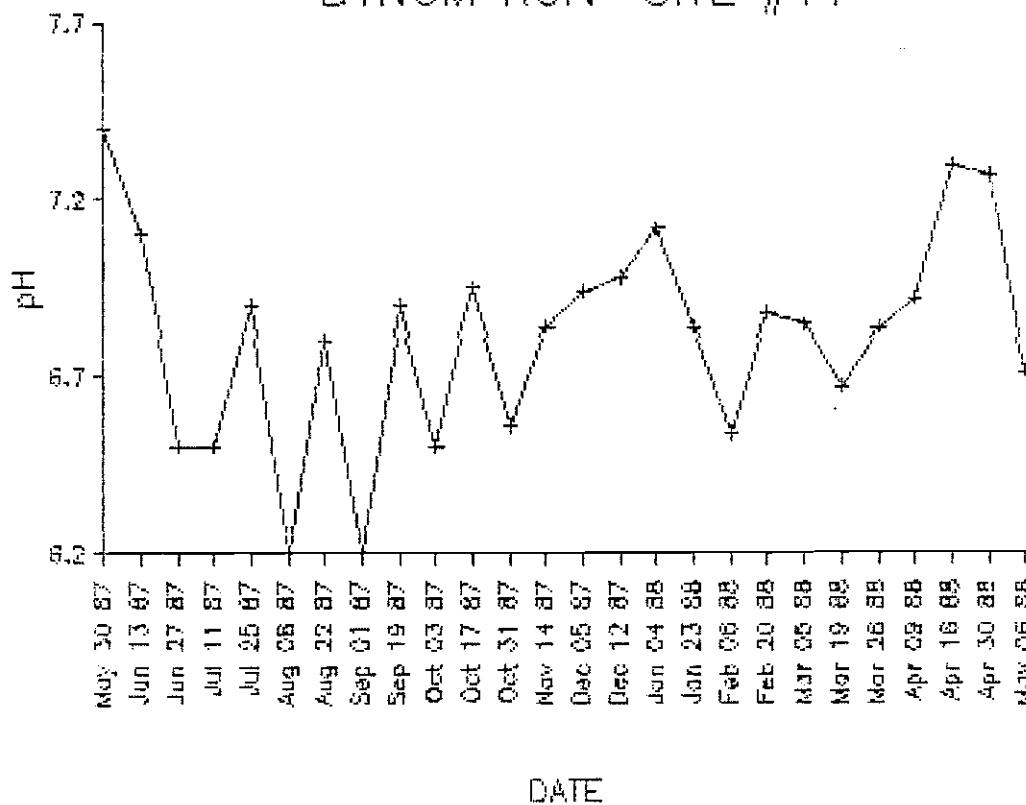




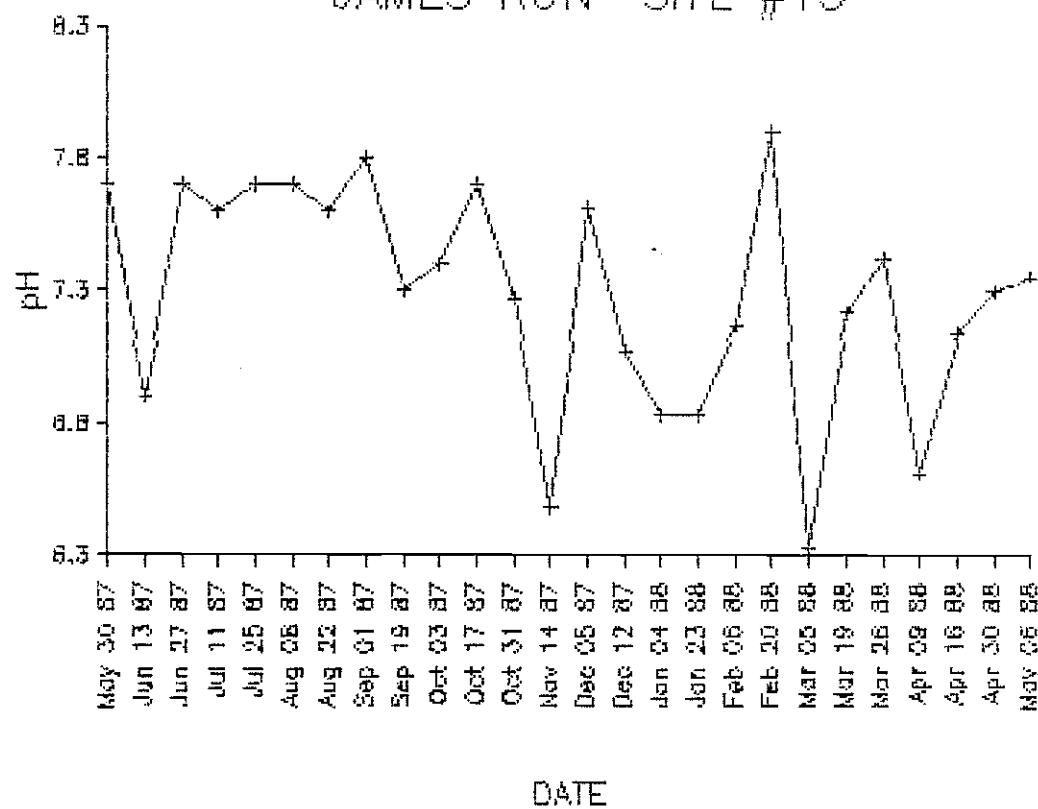
JAMES RUN SITE #12



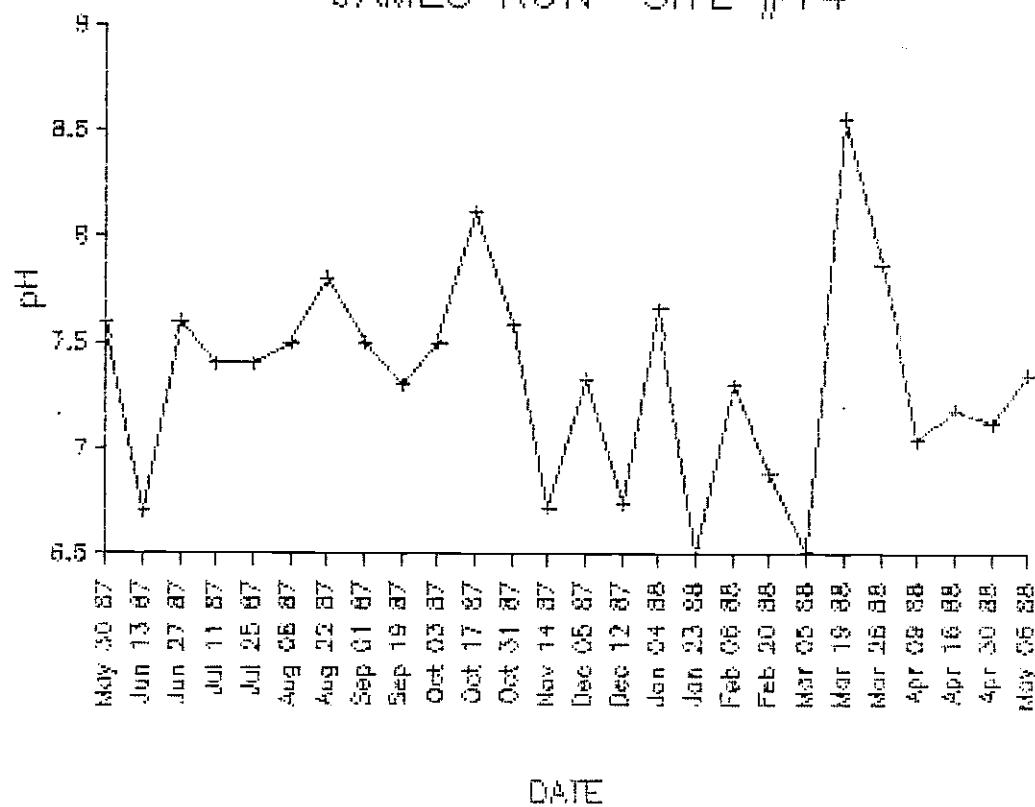
BYNUM RUN SITE #11



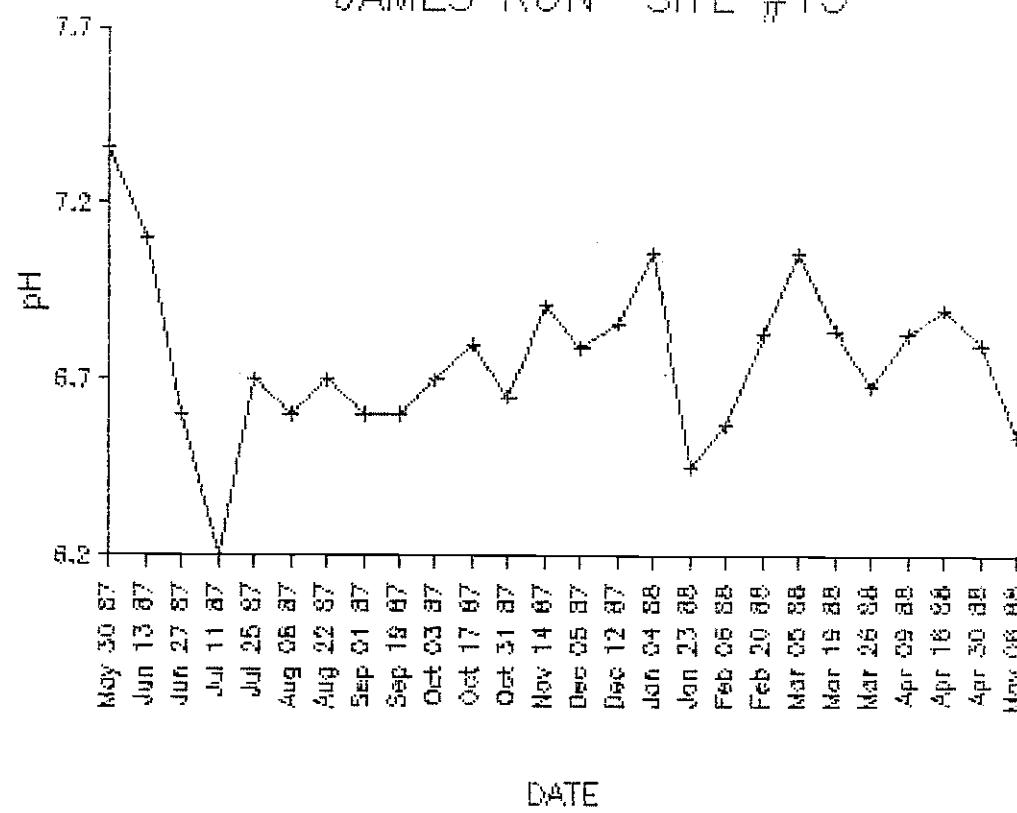
JAMES RUN SITE #13



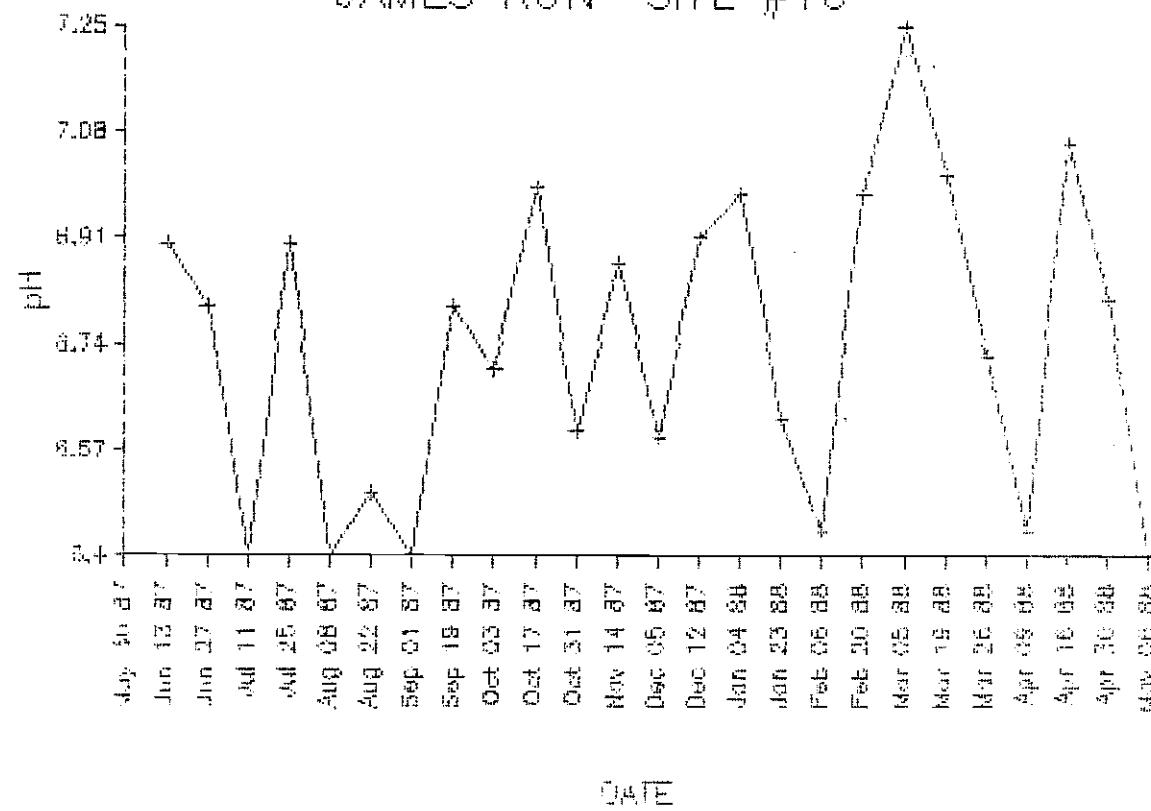
JAMES RUN SITE #14



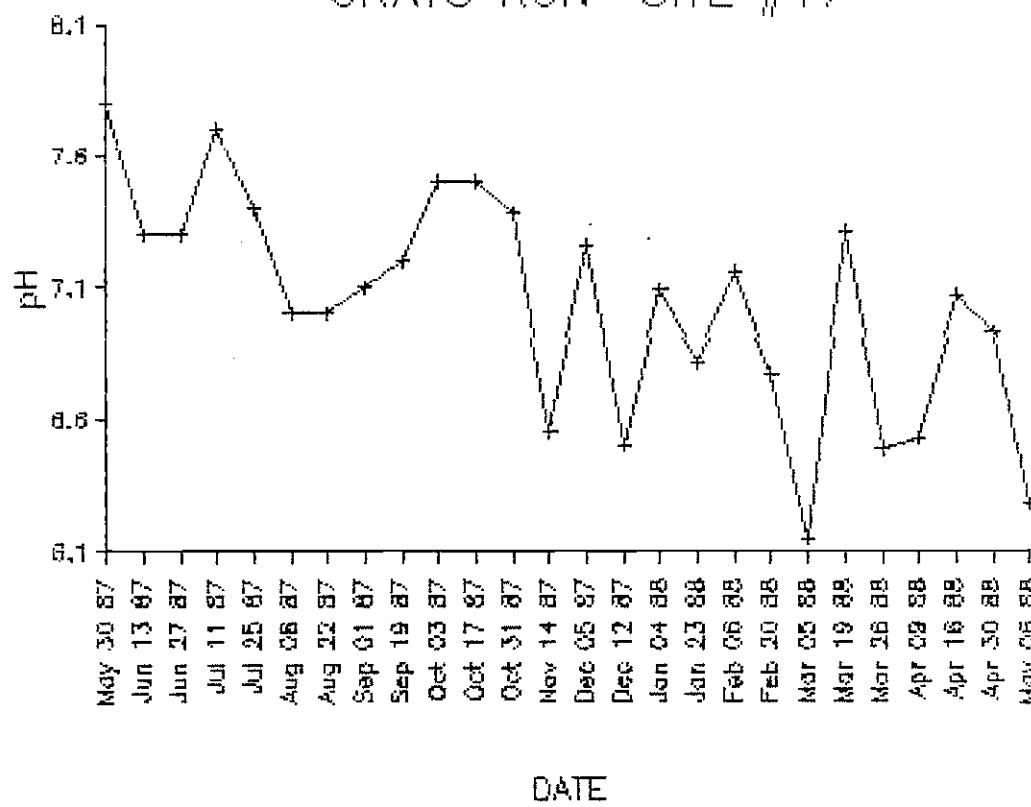
JAMES RUN SITE #15



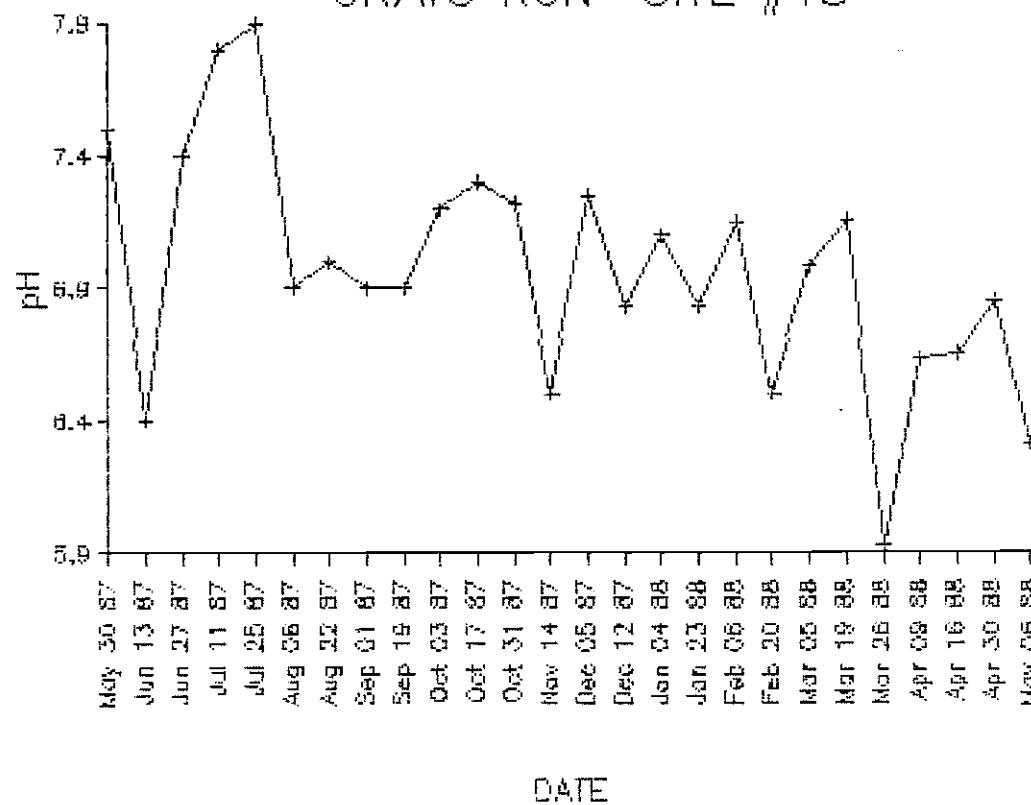
JAMES RUN SITE #15



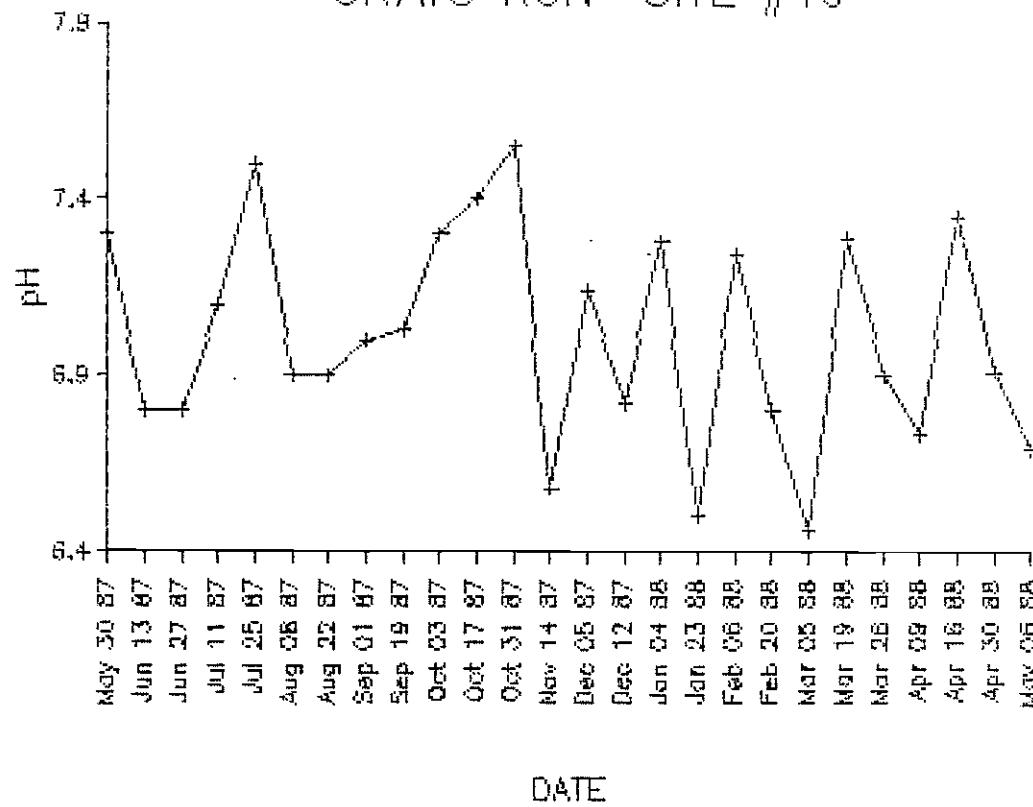
GRAYS RUN SITE #17



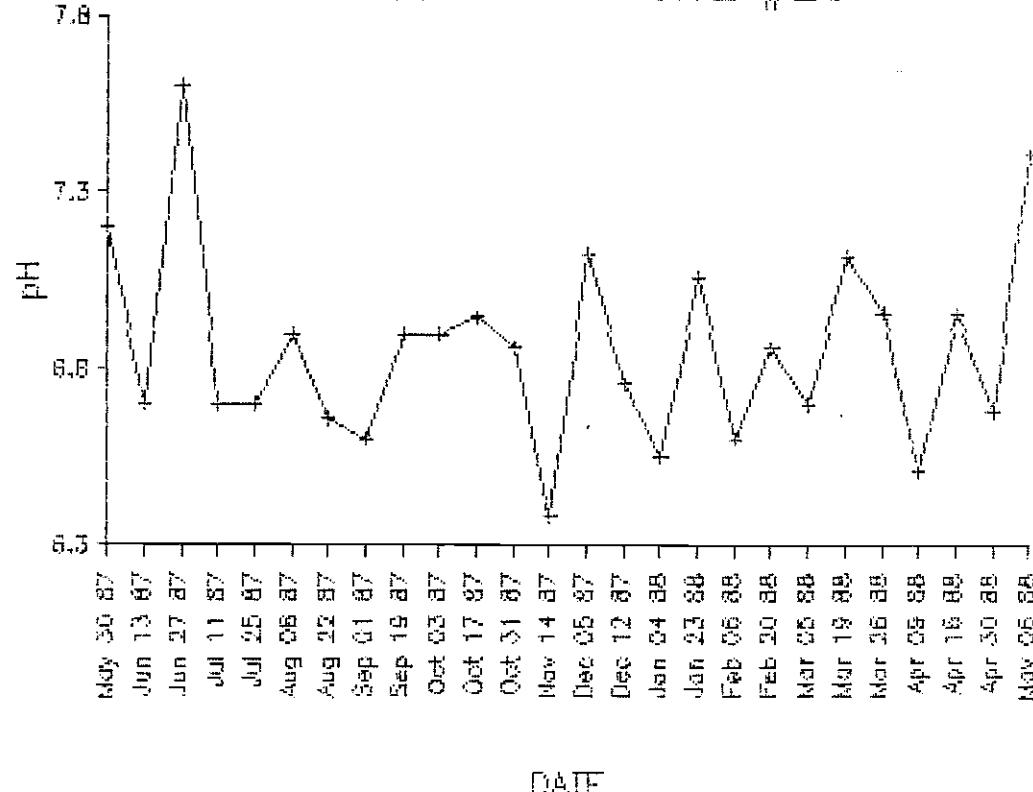
GRAYS RUN SITE #100



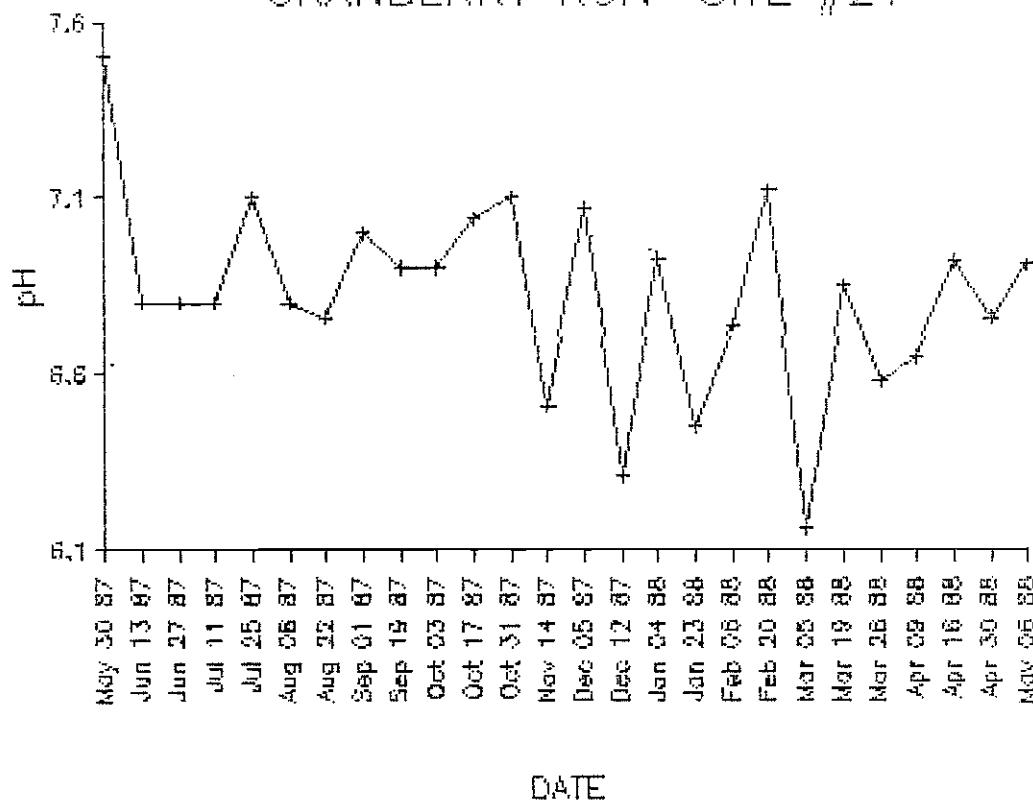
GRAYS RUN SITE #19



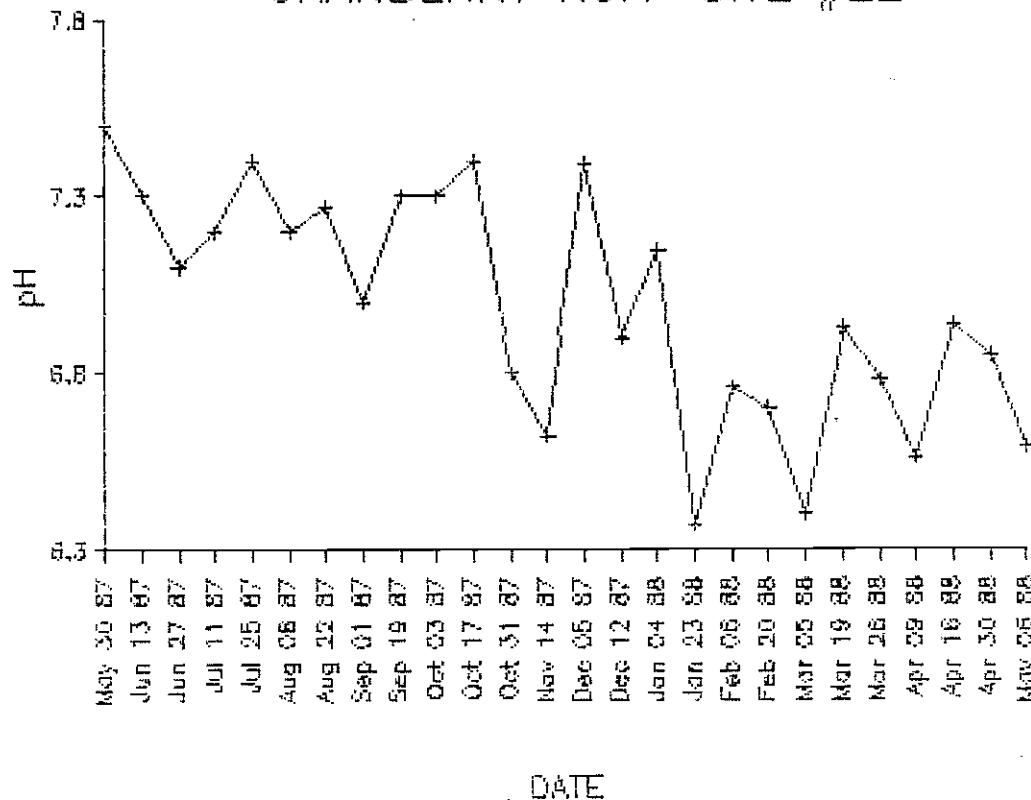
GRAYS RUN SITE #20



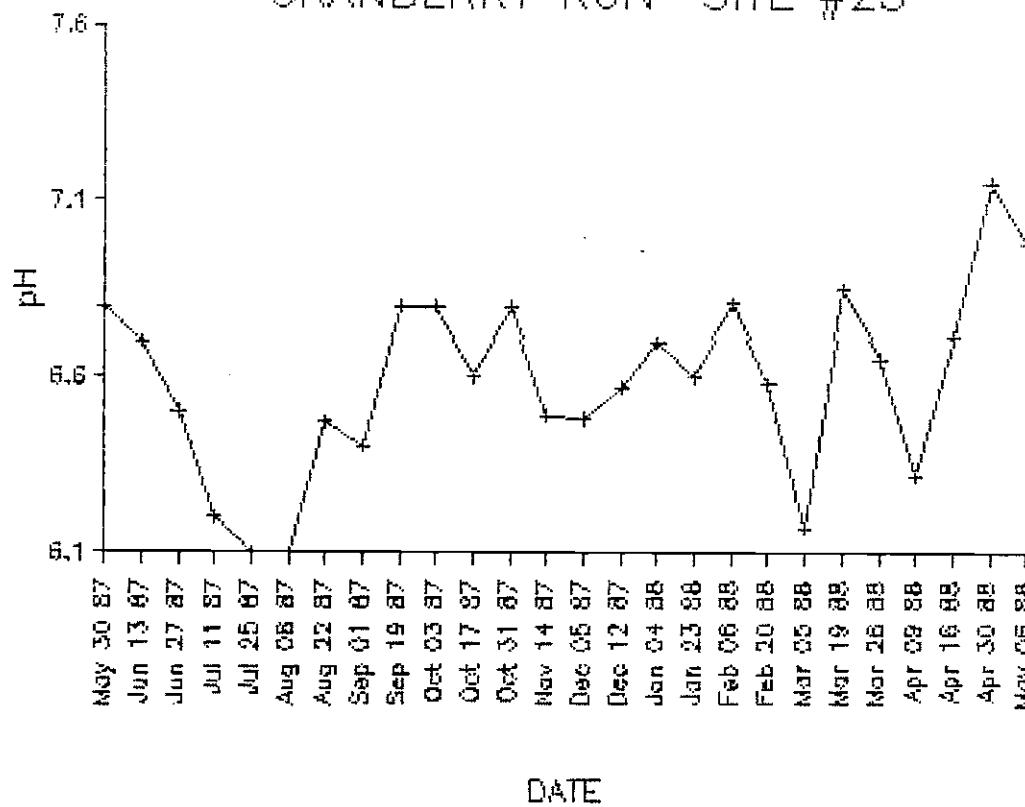
CRANBERRY RUN SITE #21



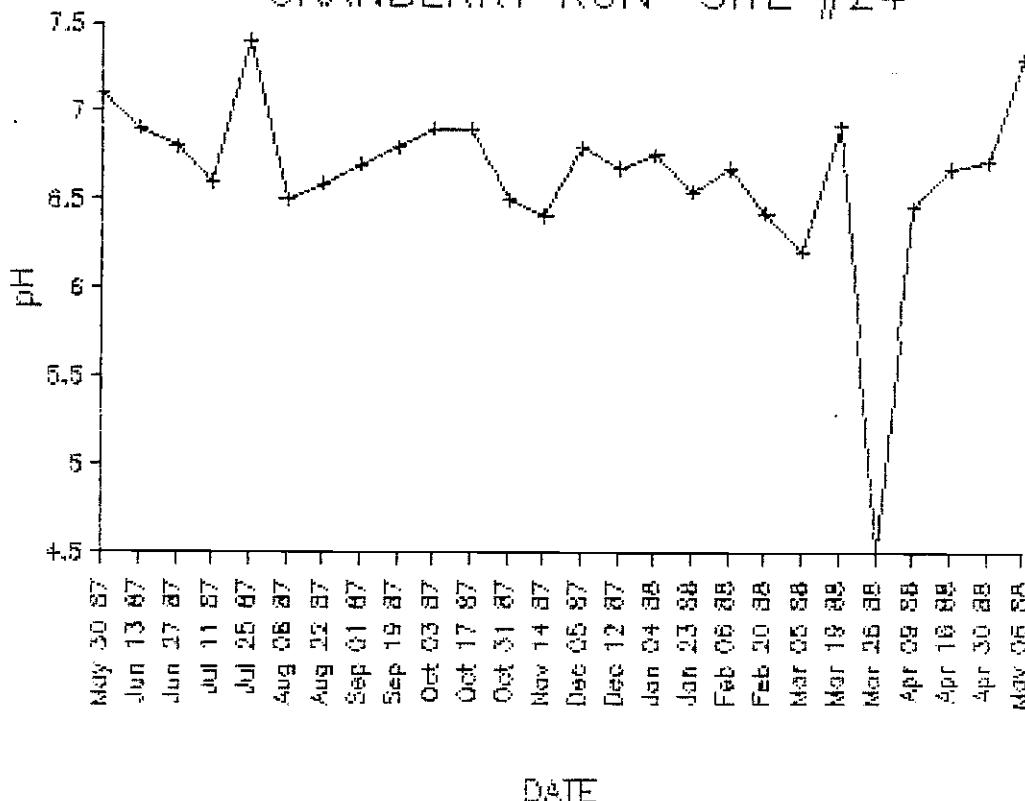
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23

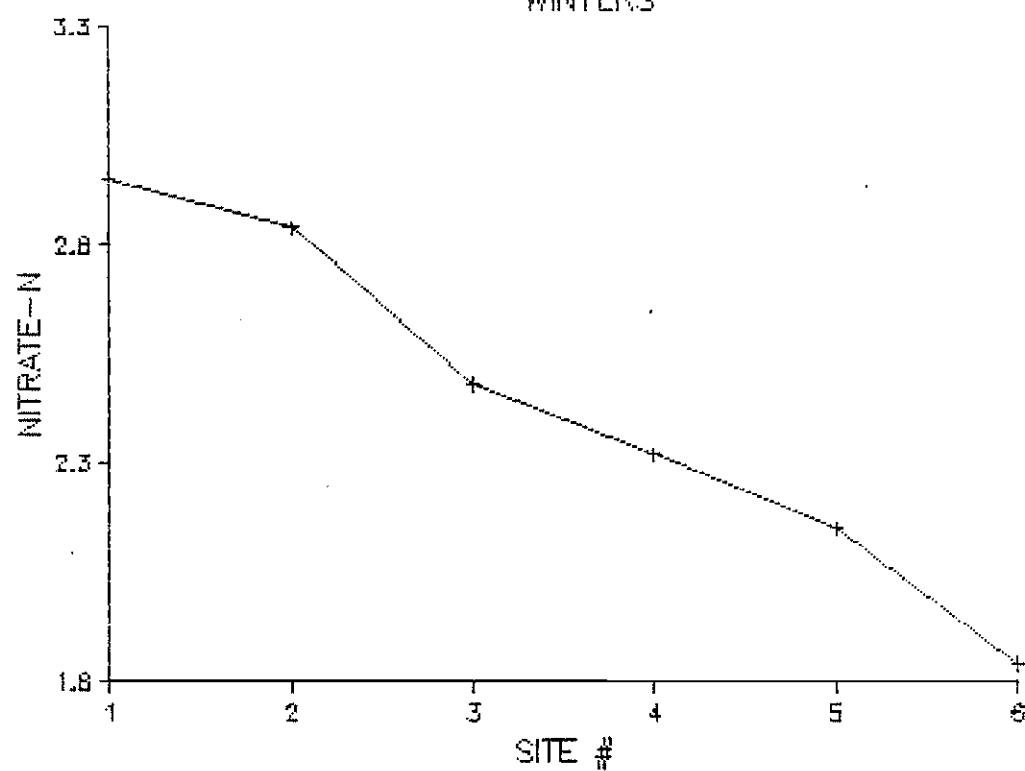


CRANBERRY RUN SITE #24

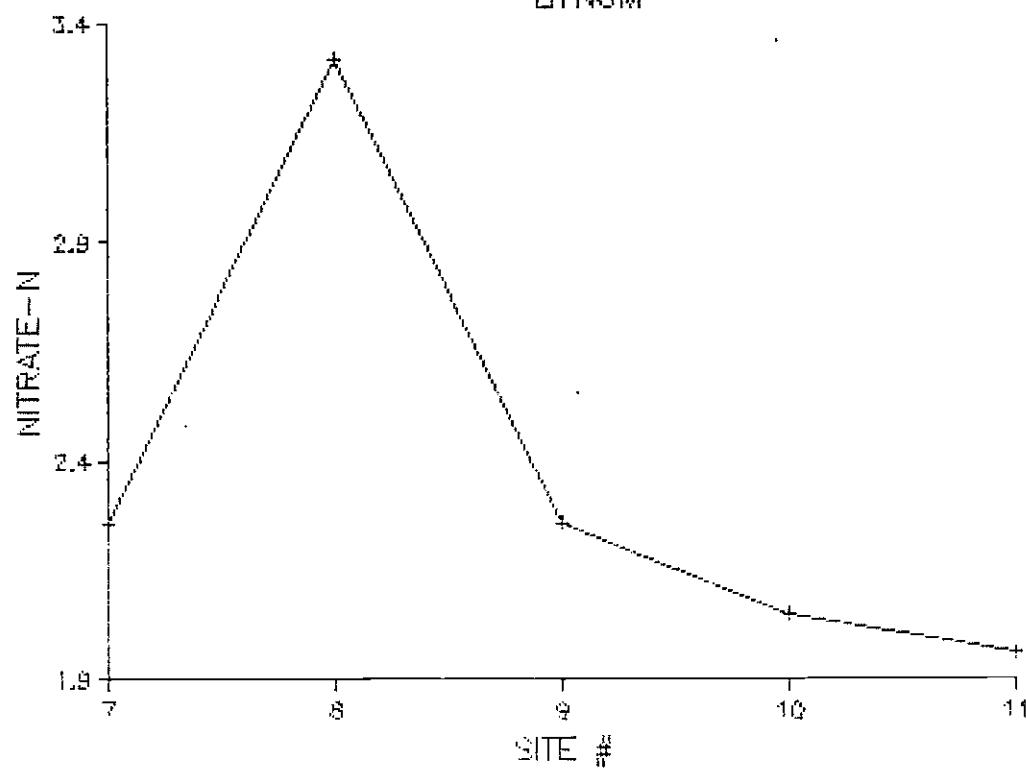


Nitrate-N
(mg/l)

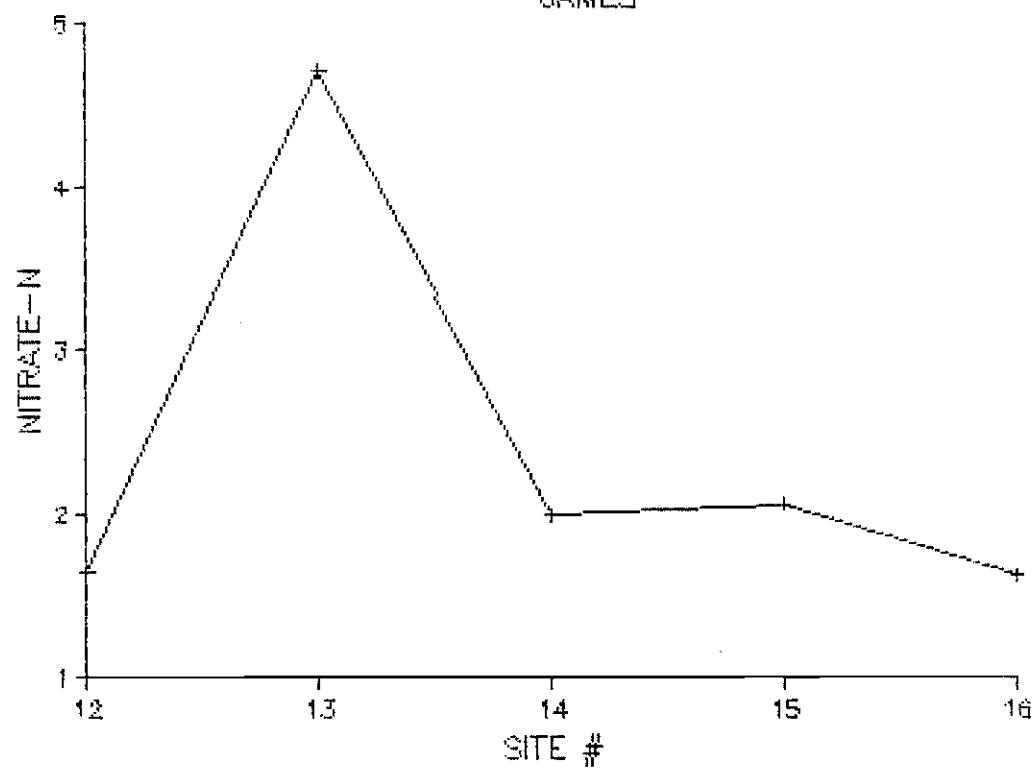
YEARLY AVERAGES
WINTERS



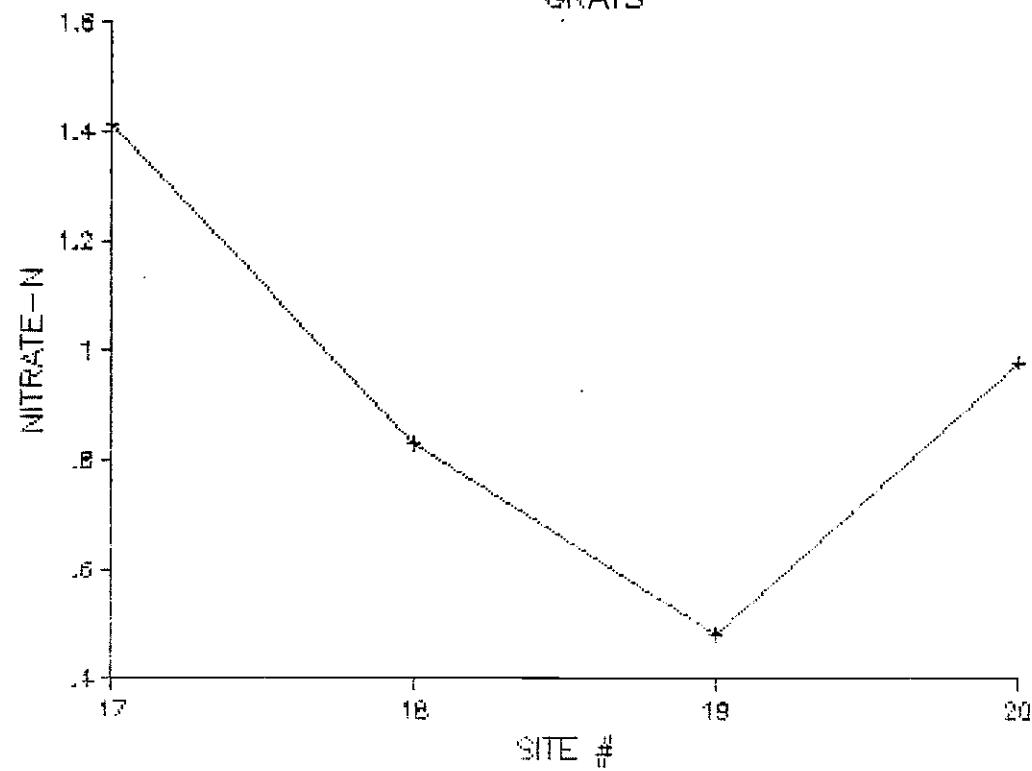
YEARLY AVERAGES
BYNUM



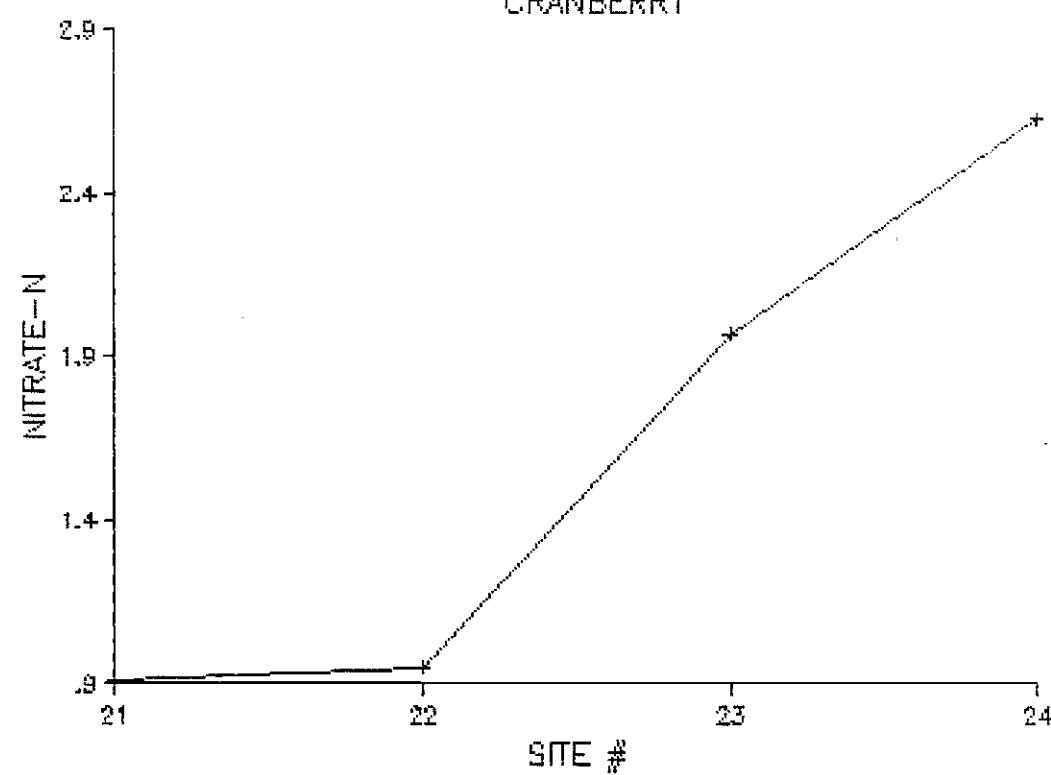
YEARLY AVERAGES
JAMES



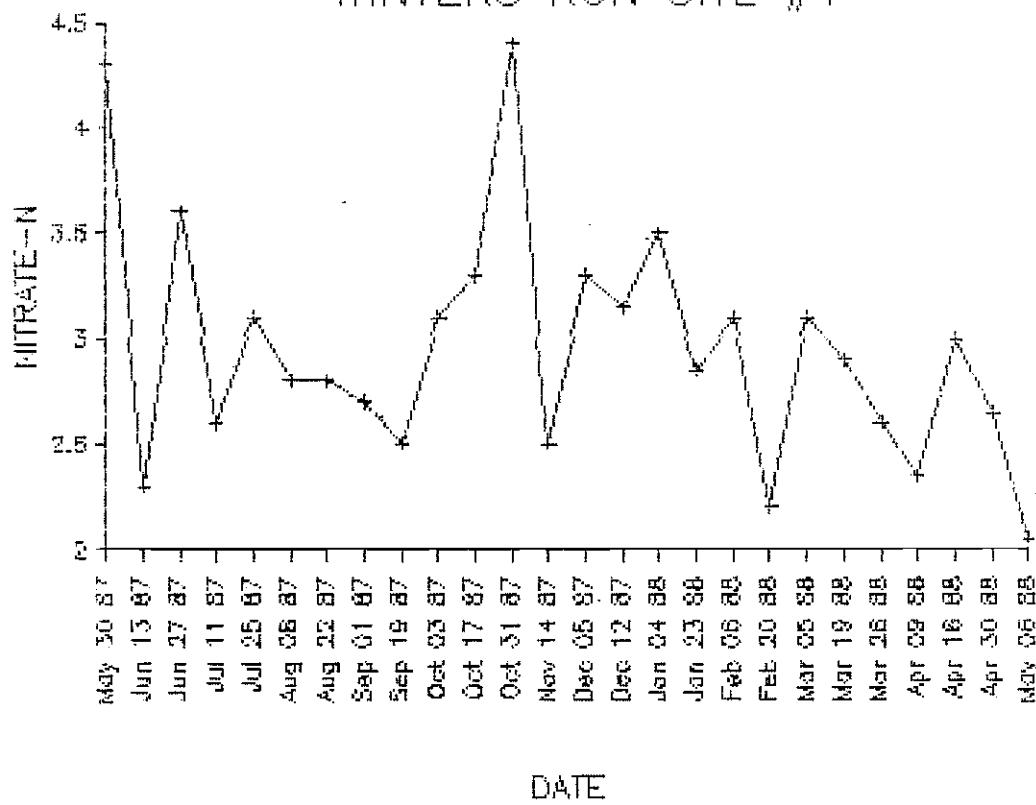
YEARLY AVERAGES
GRAYS



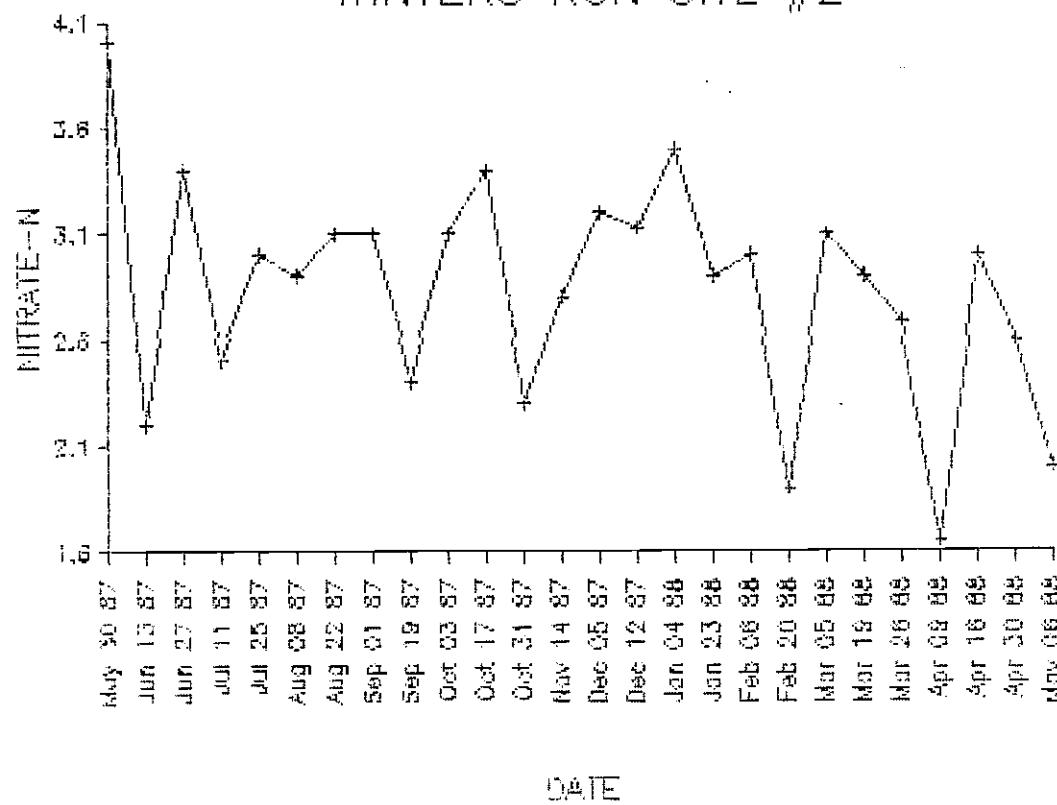
YEARLY AVERAGES
CRANBERRY



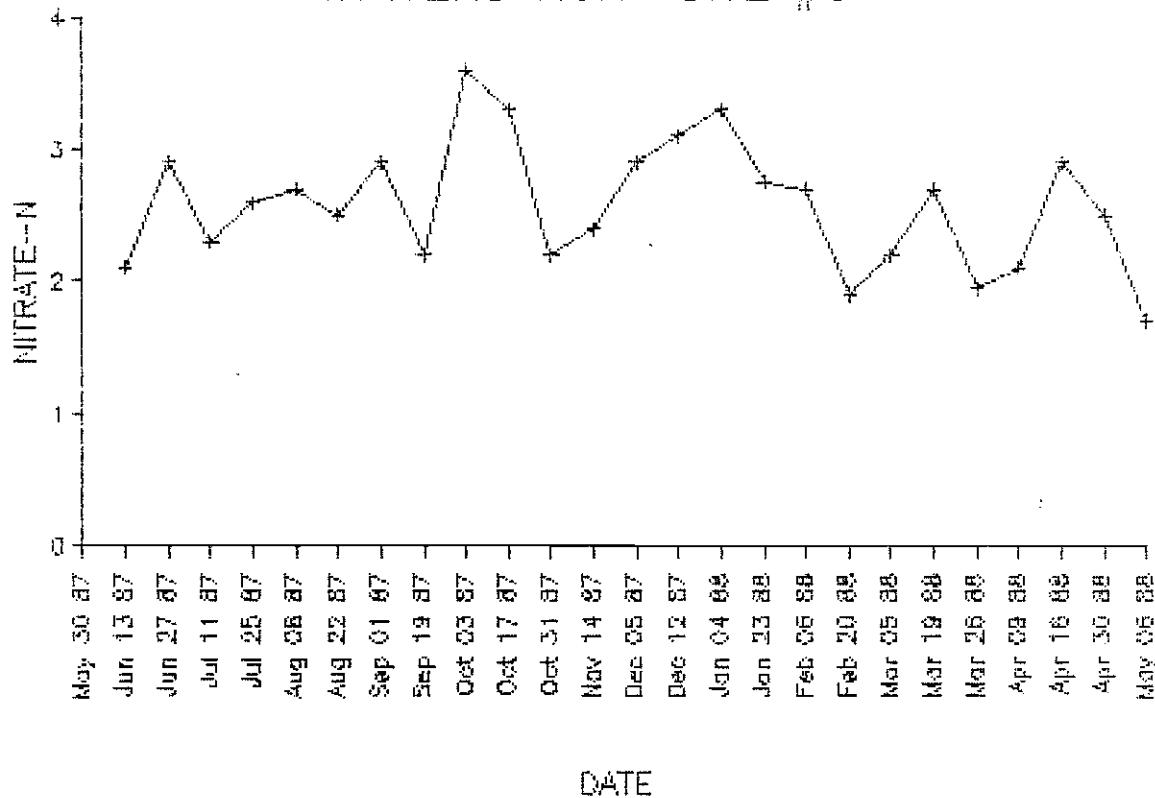
WINTERS RUN SITE #1



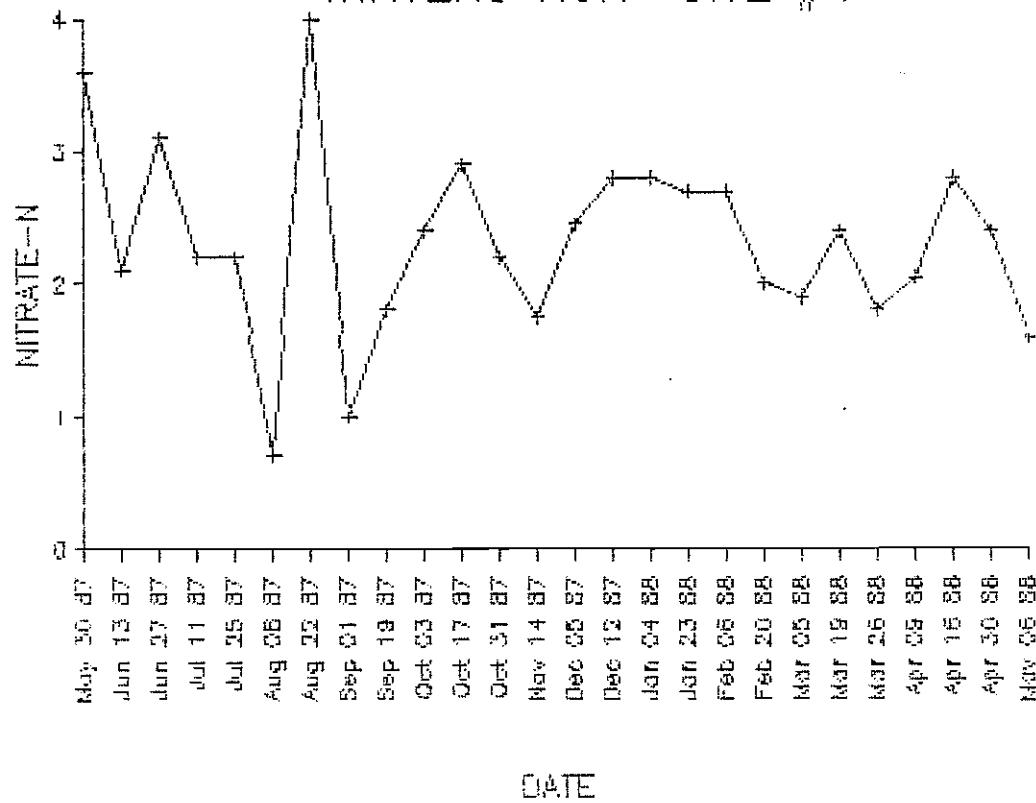
WINTERS RUN SITE #2



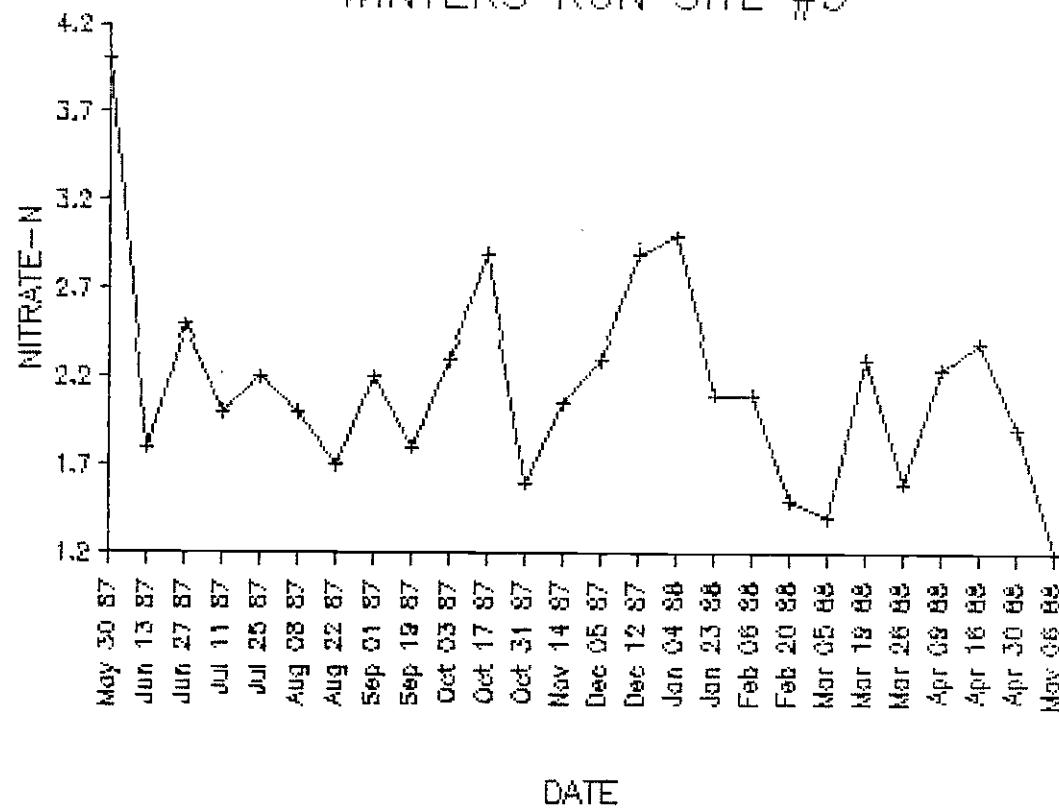
WINTERS RUN SITE #4



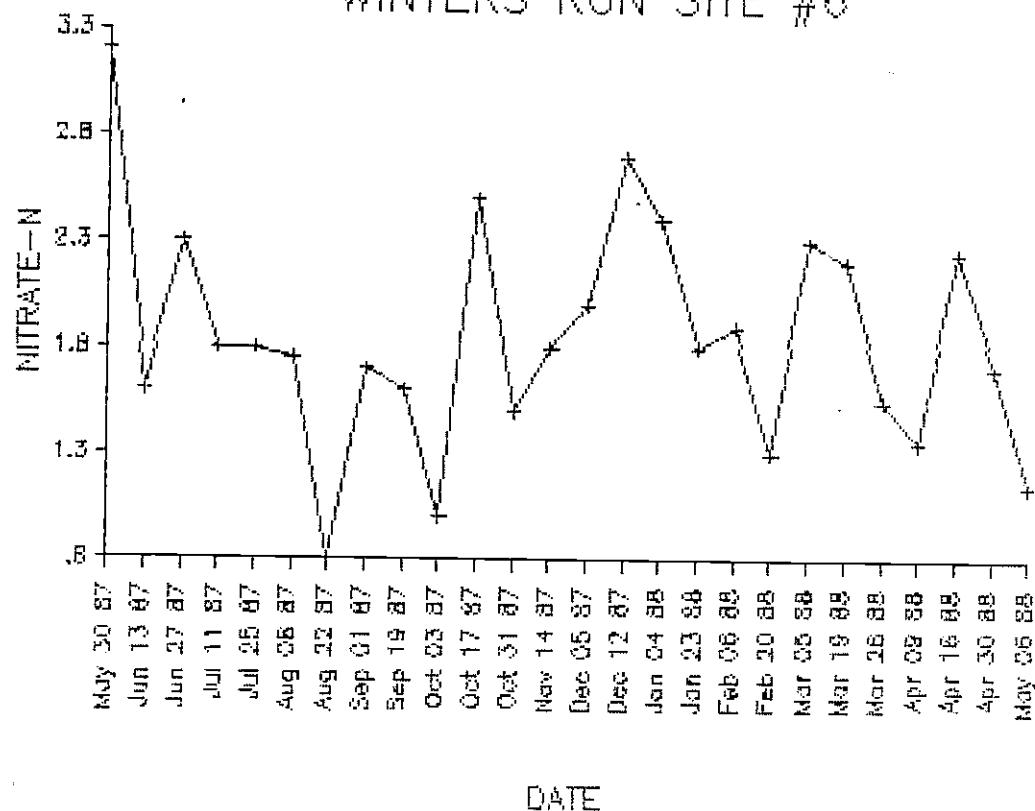
WINTERS RUN SITE #4



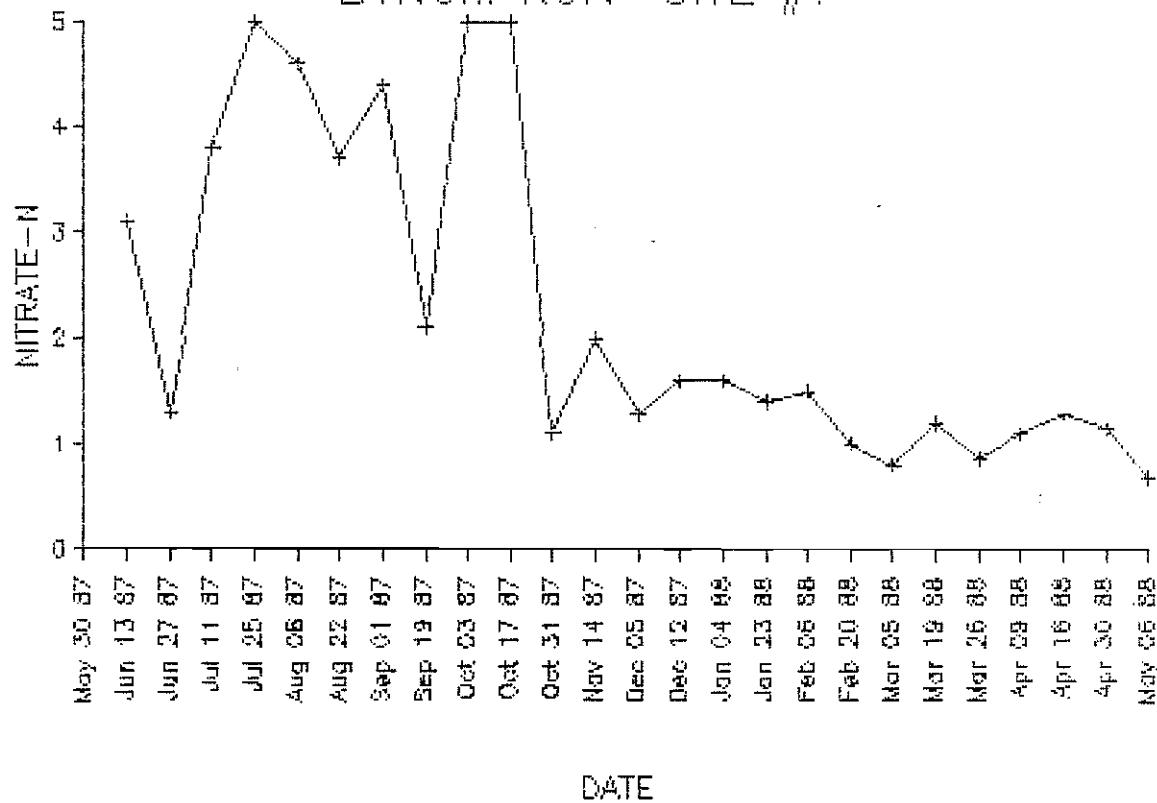
WINTERS RUN SITE #5



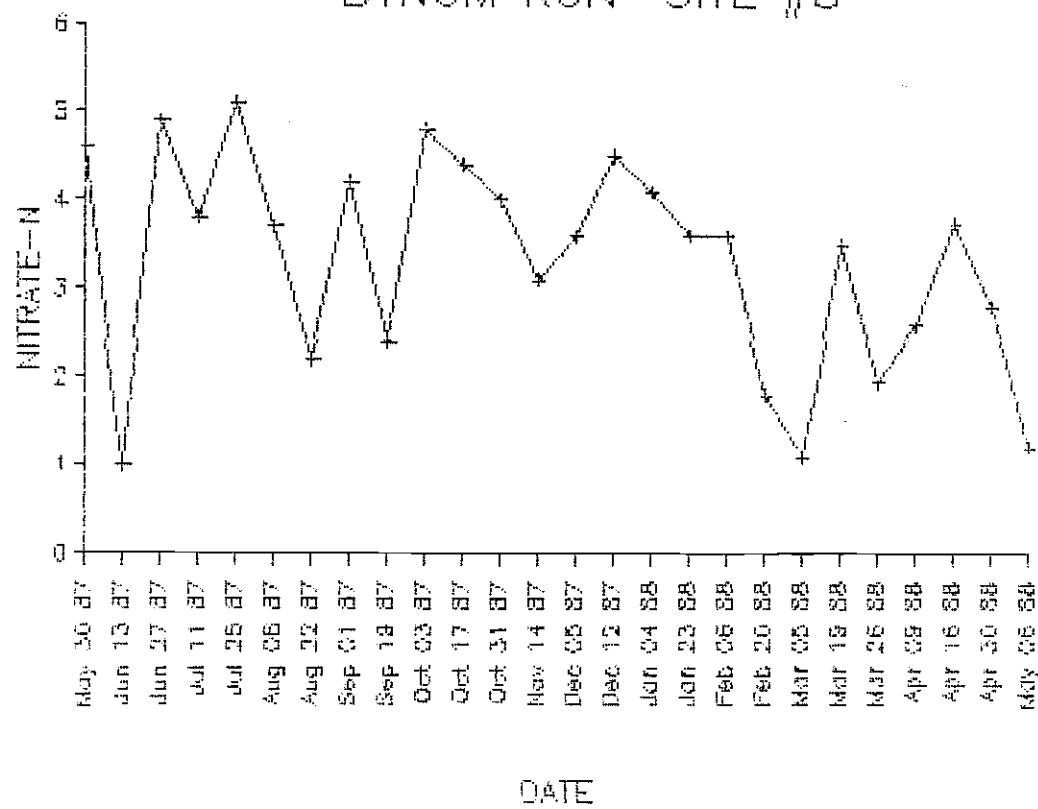
WINTERS RUN SITE #6



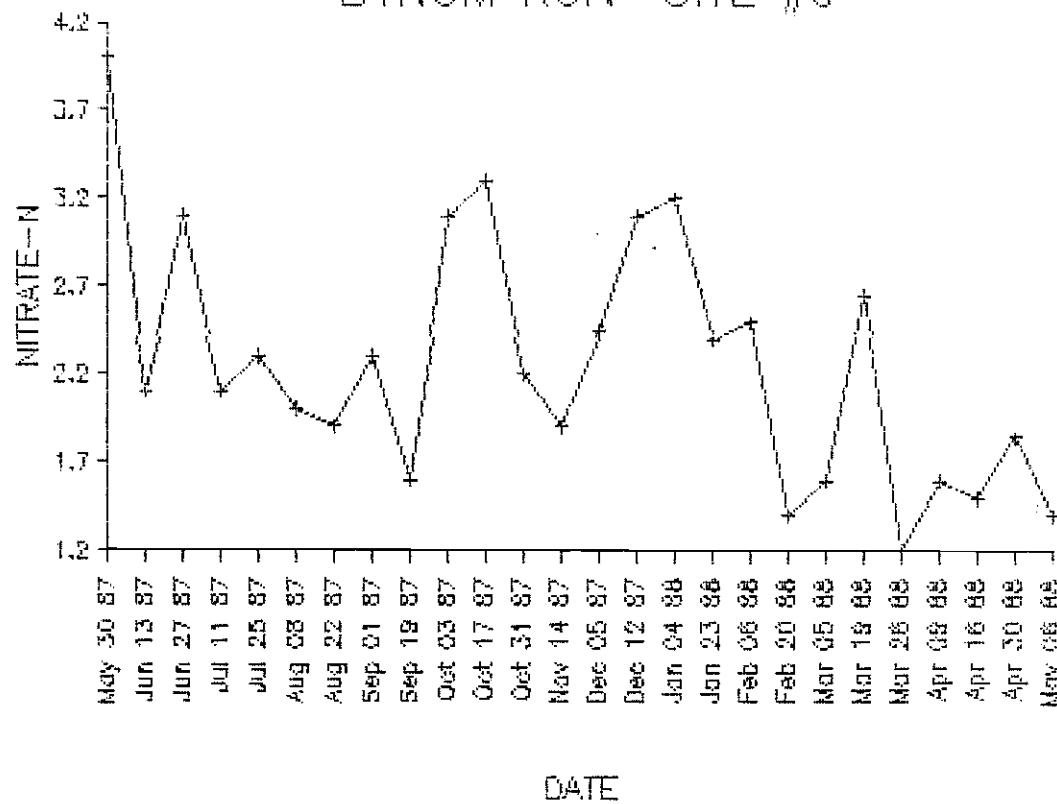
BYNUM RUN SITE #7



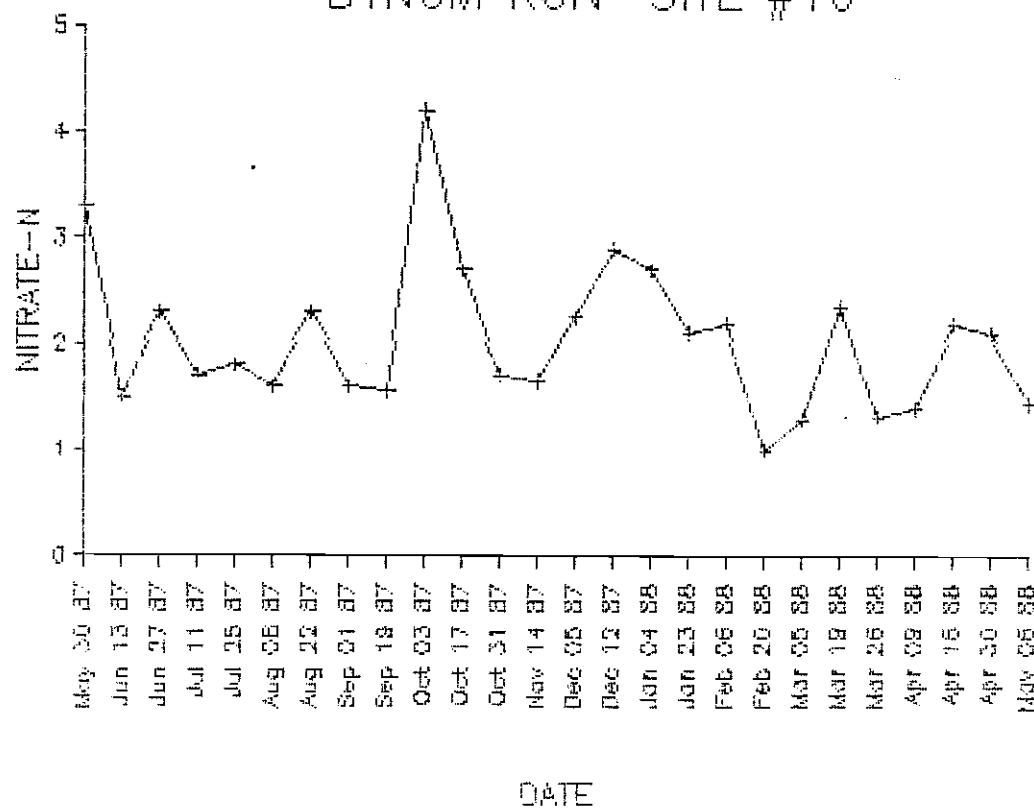
BYNUM RUN SITE #8



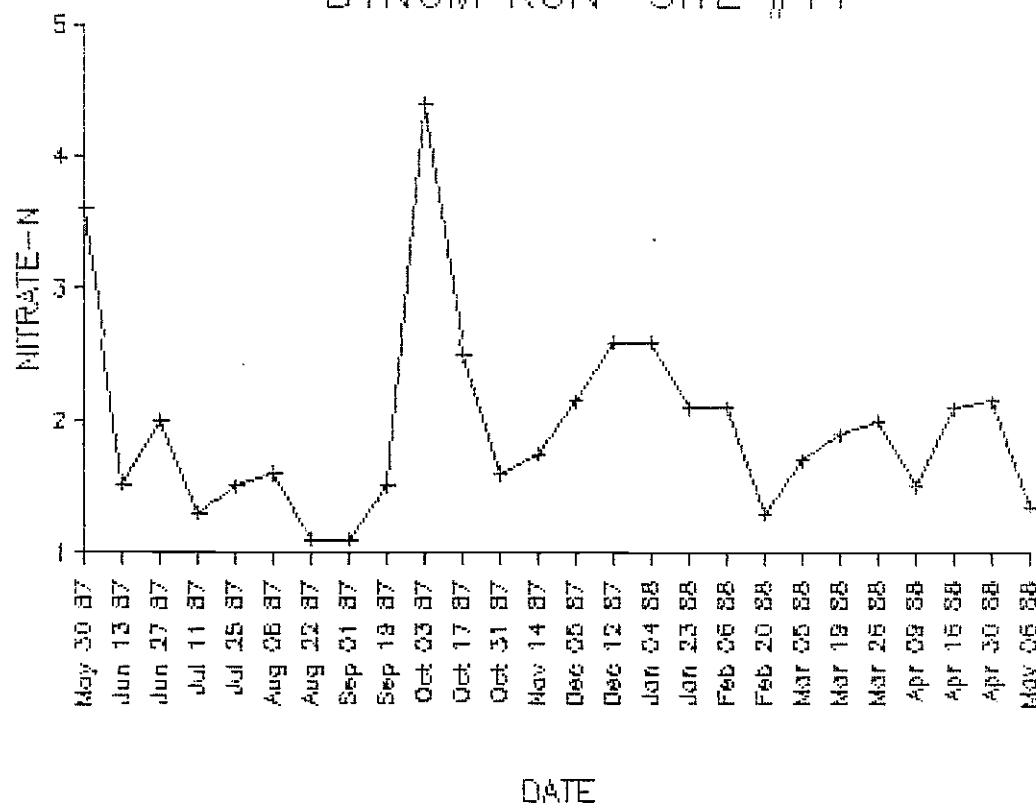
BYNUM RUN SITE #9



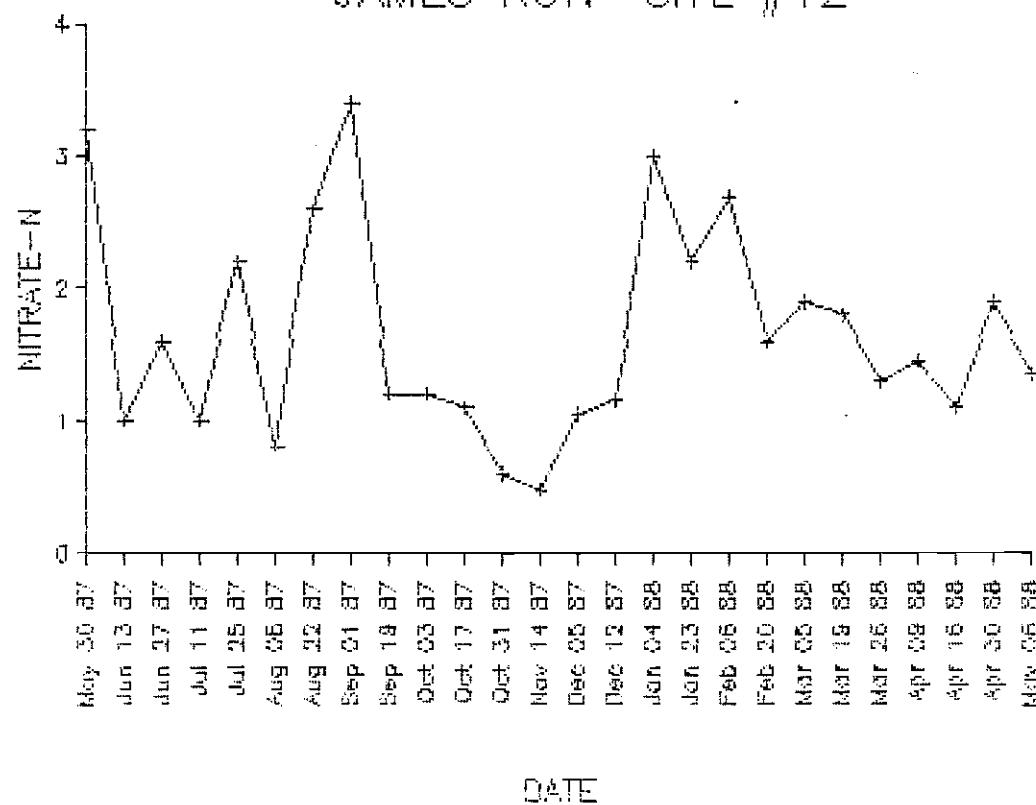
BYNUM RUN SITE #10



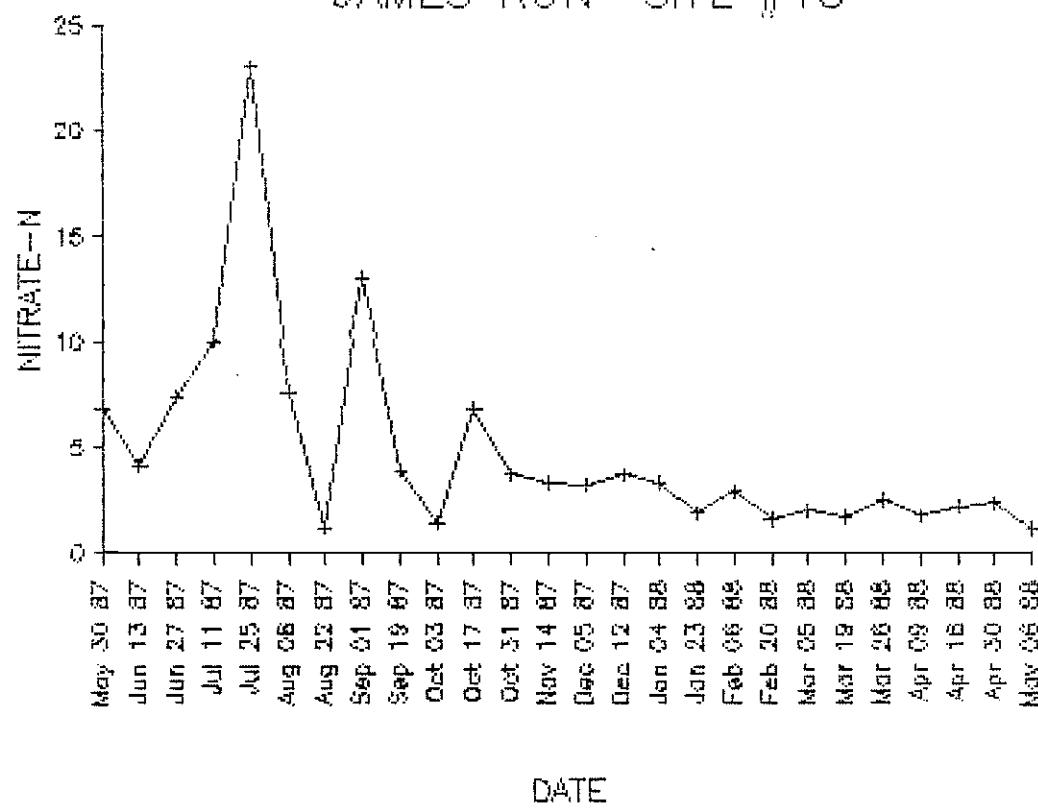
BYNUM RUN SITE #11



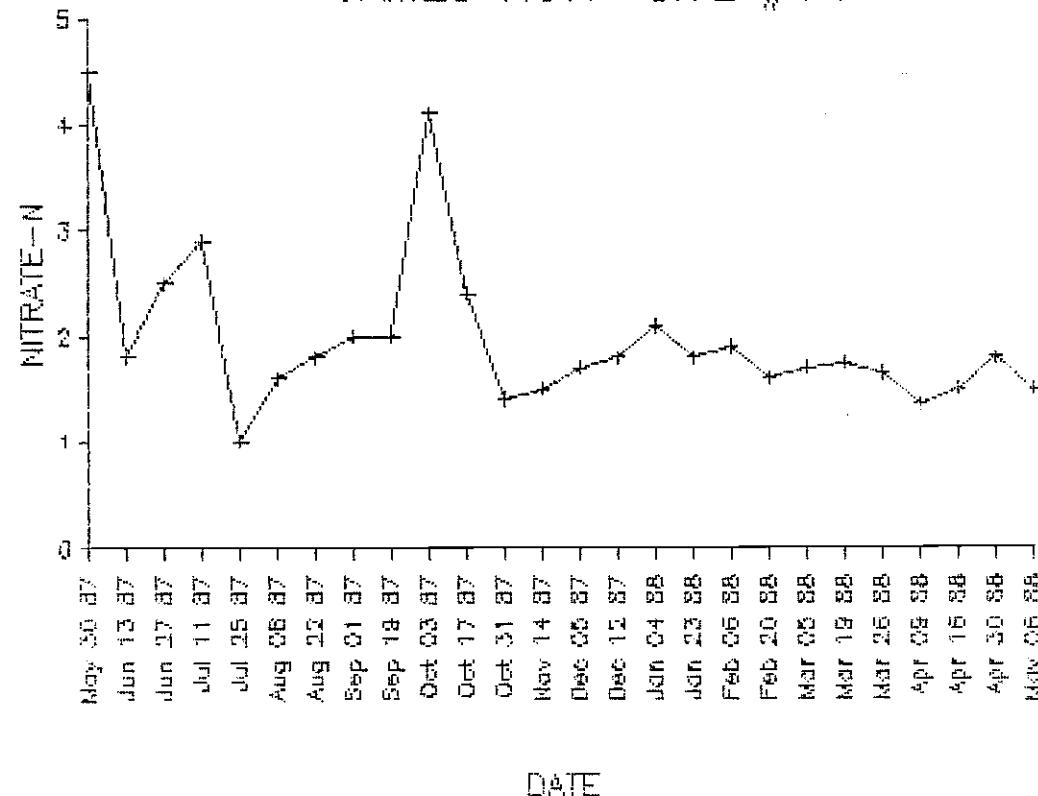
JAMES RUN SITE #12



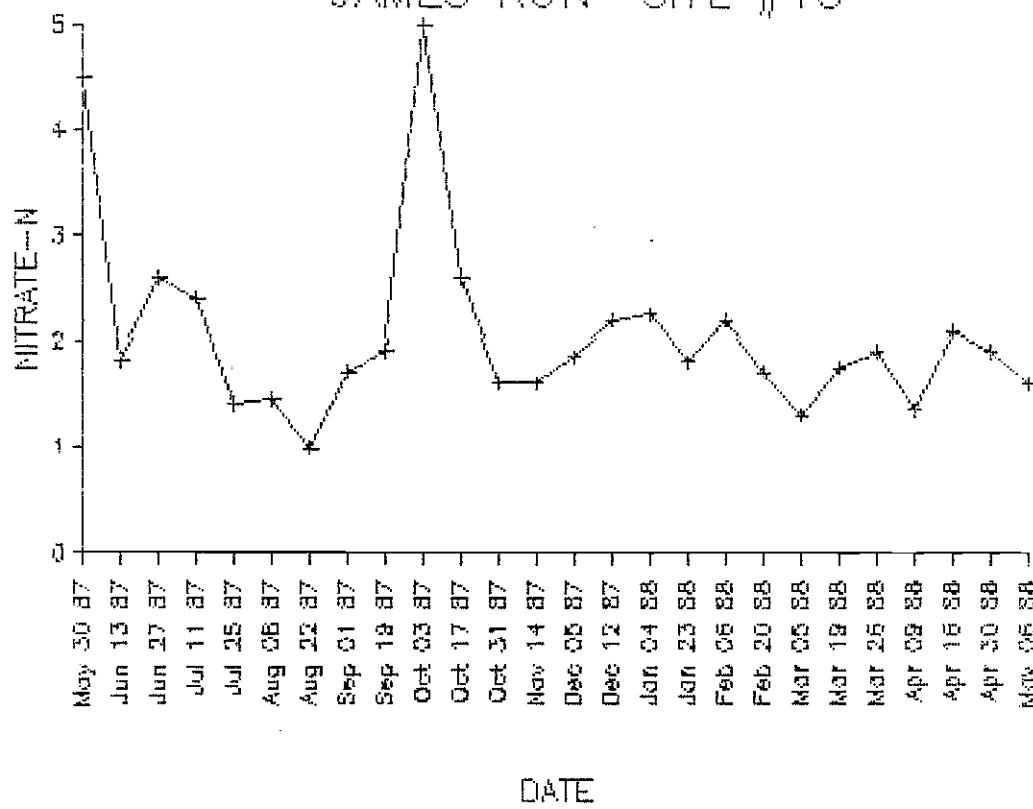
JAMES RUN SITE #13



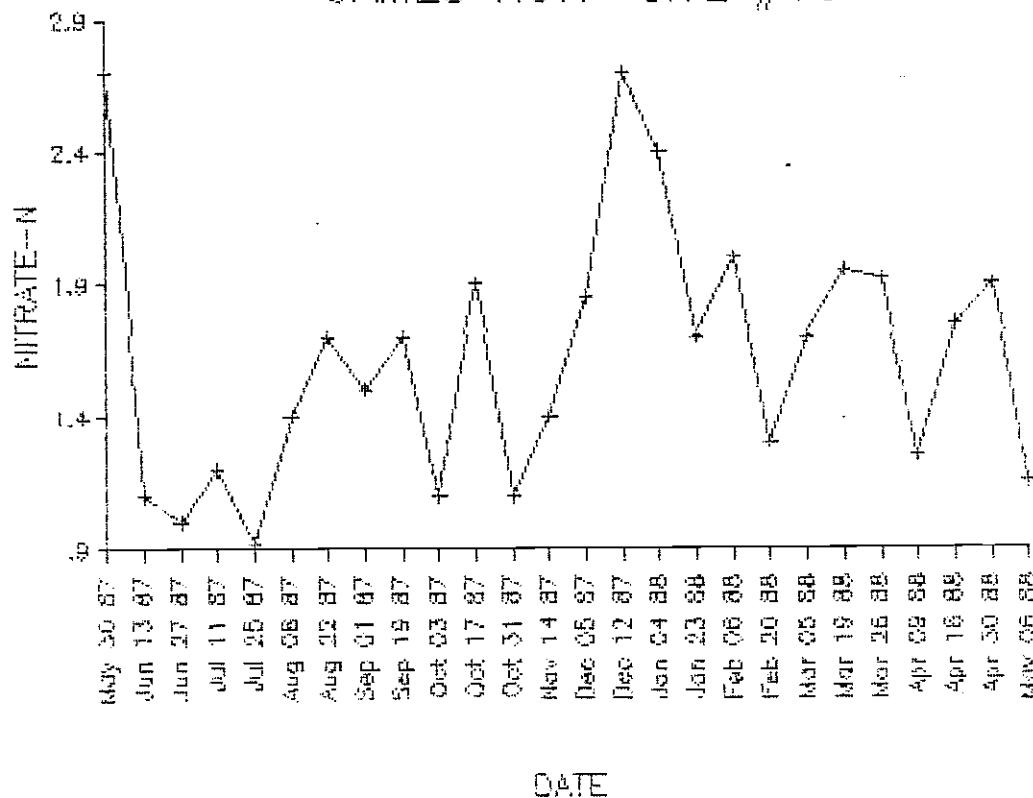
JAMES RUN SITE #14



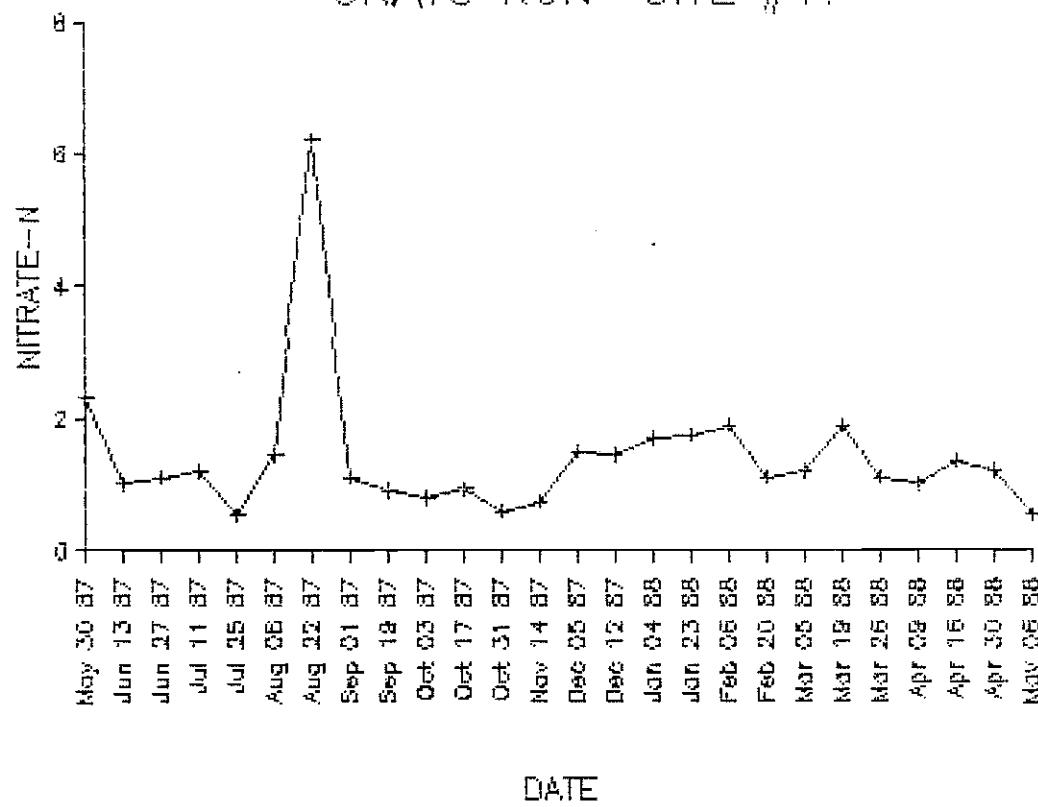
JAMES RUN SITE #15



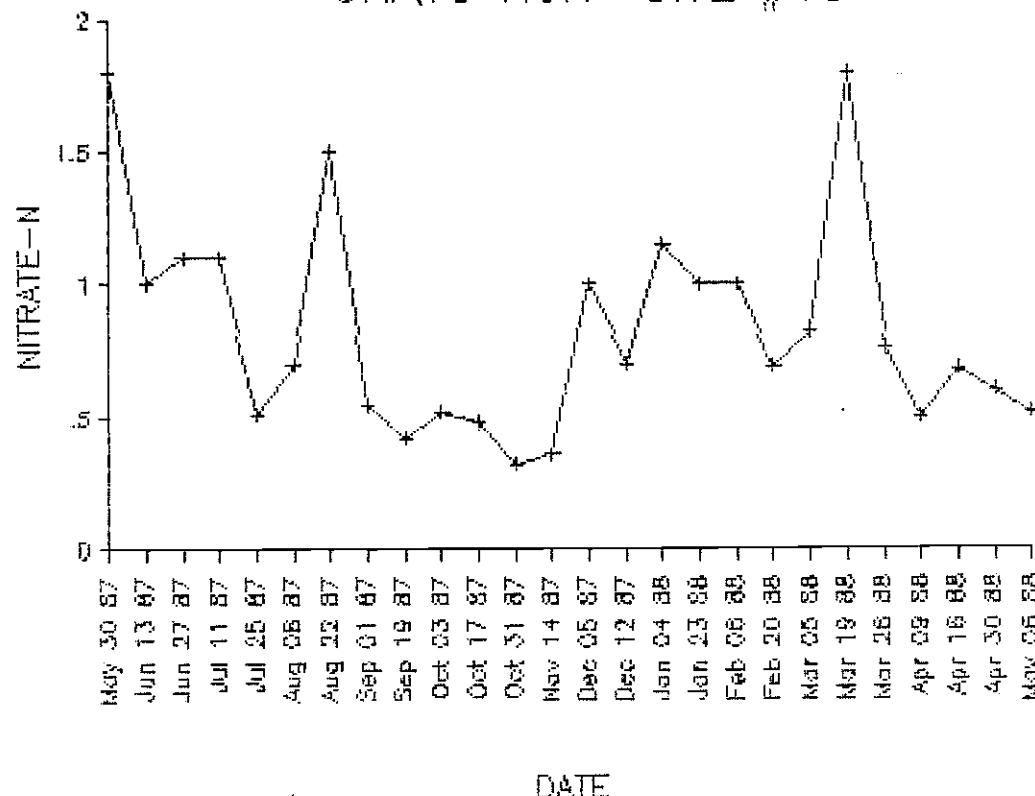
JAMES RUN SITE #16



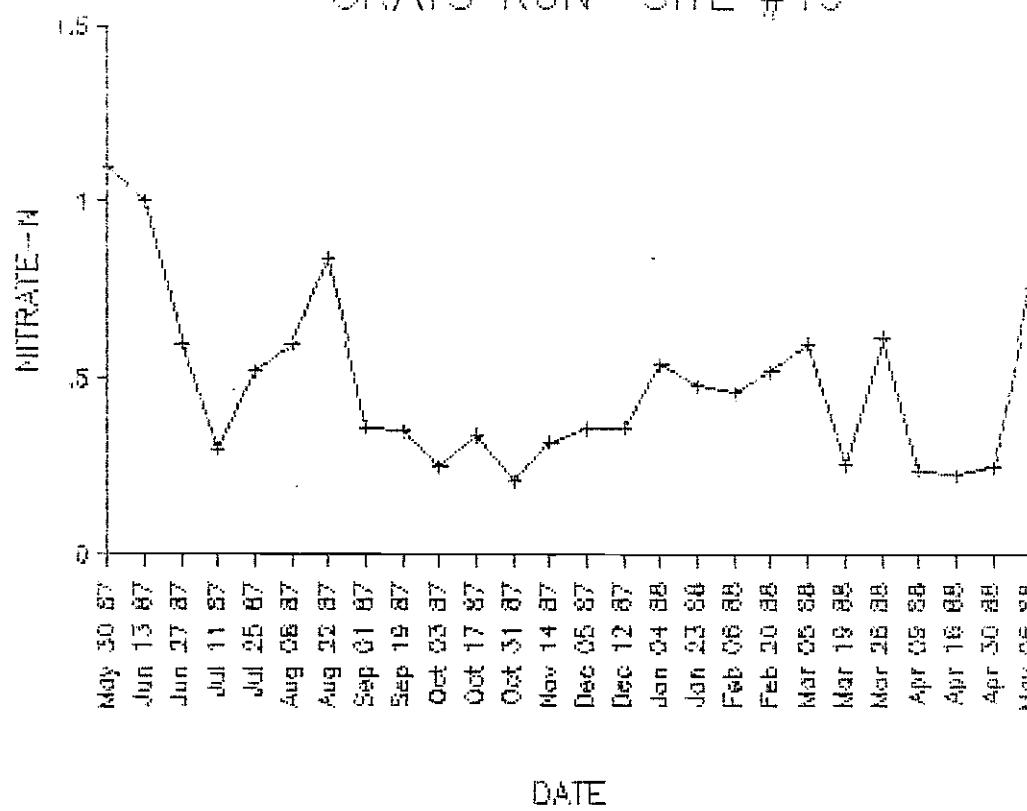
GRAYS RUN SITE #17



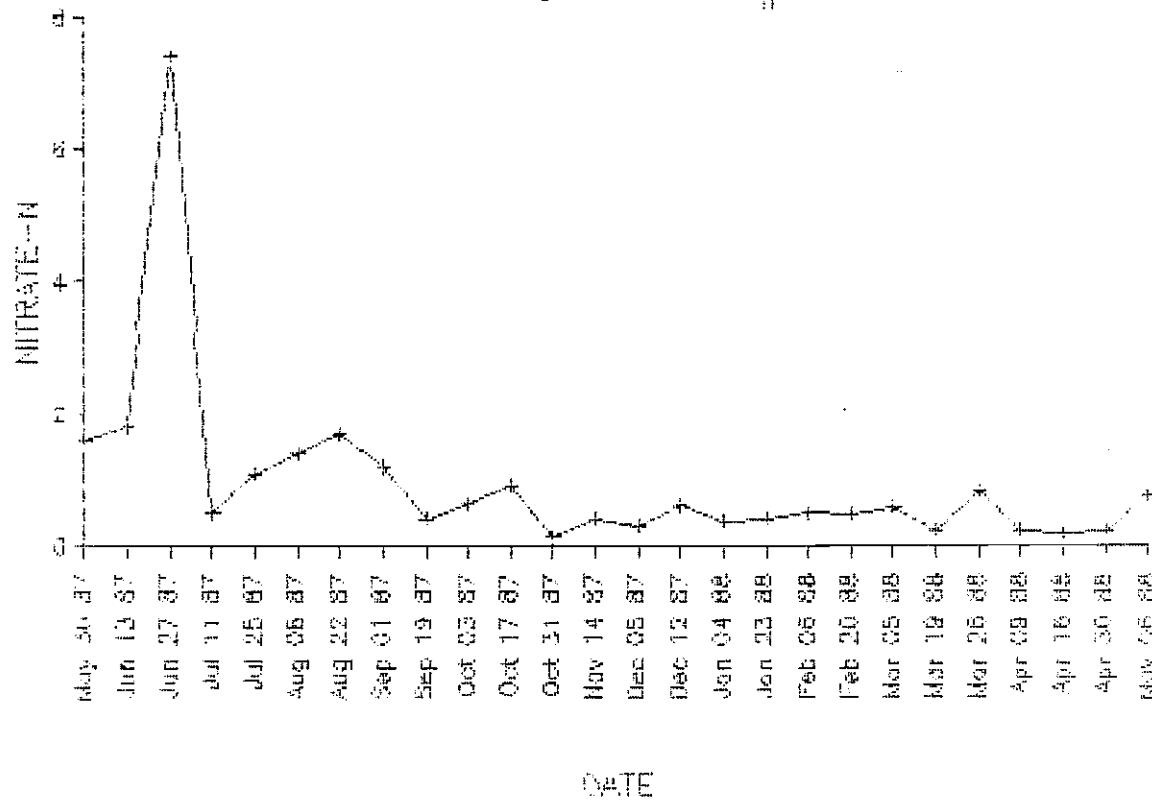
GRAYS RUN SITE #18



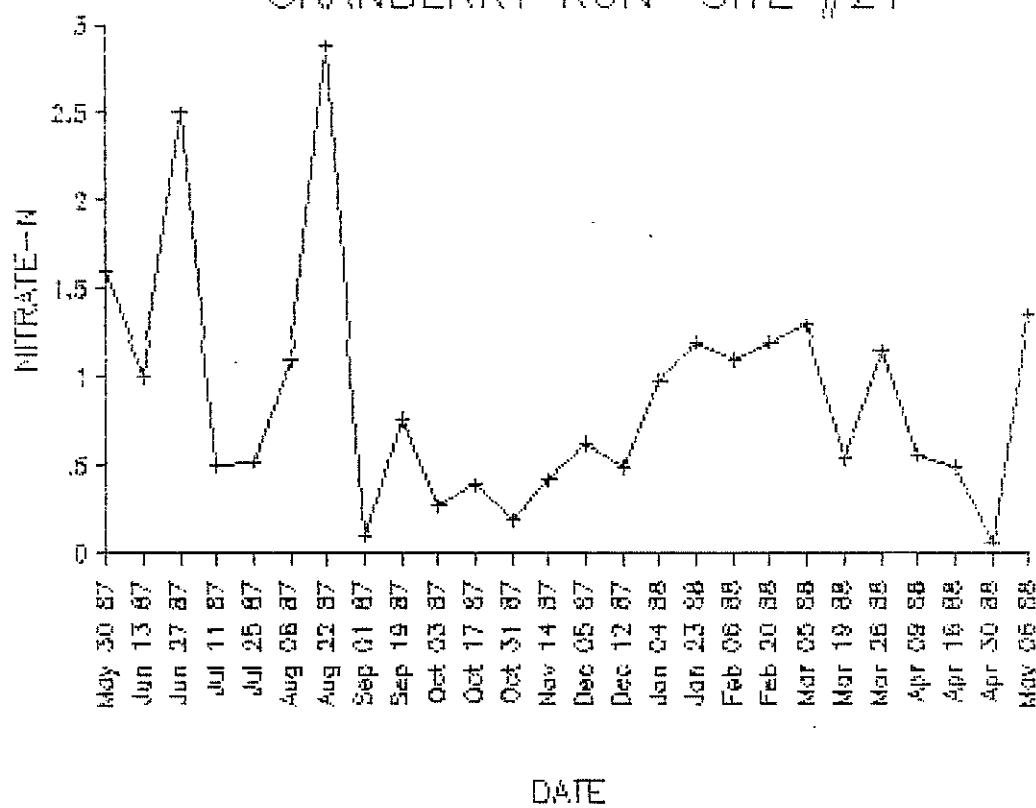
GRAYS RUN SITE #19



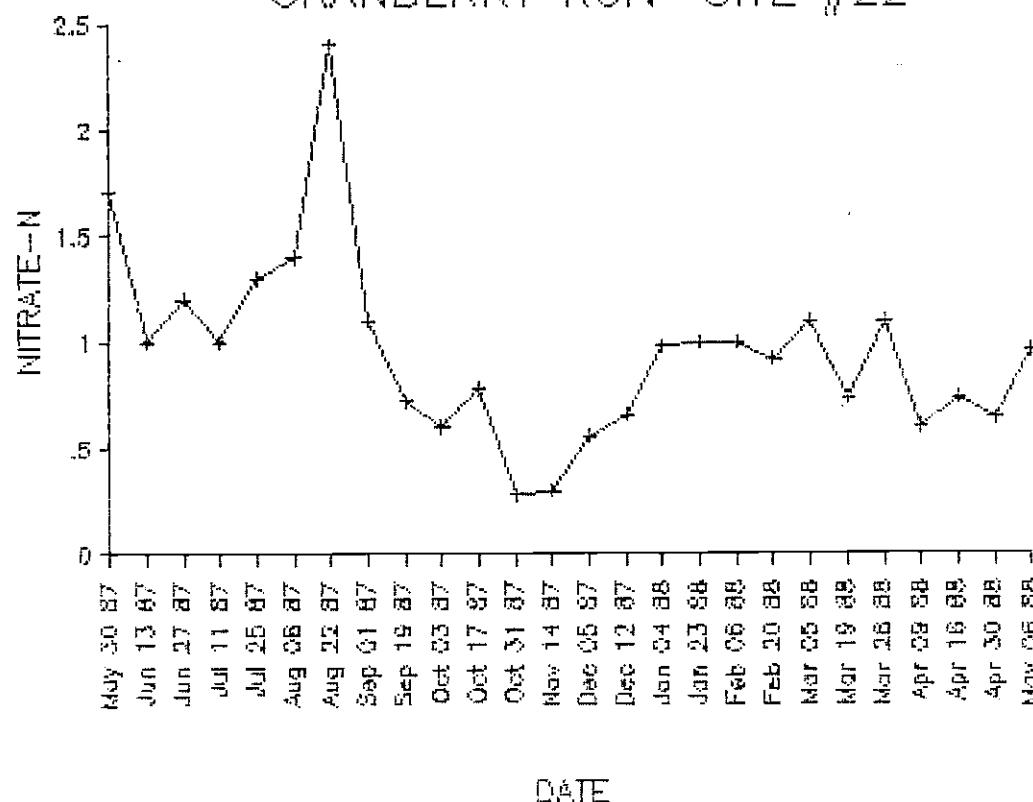
GRAYS RUN SITE #20



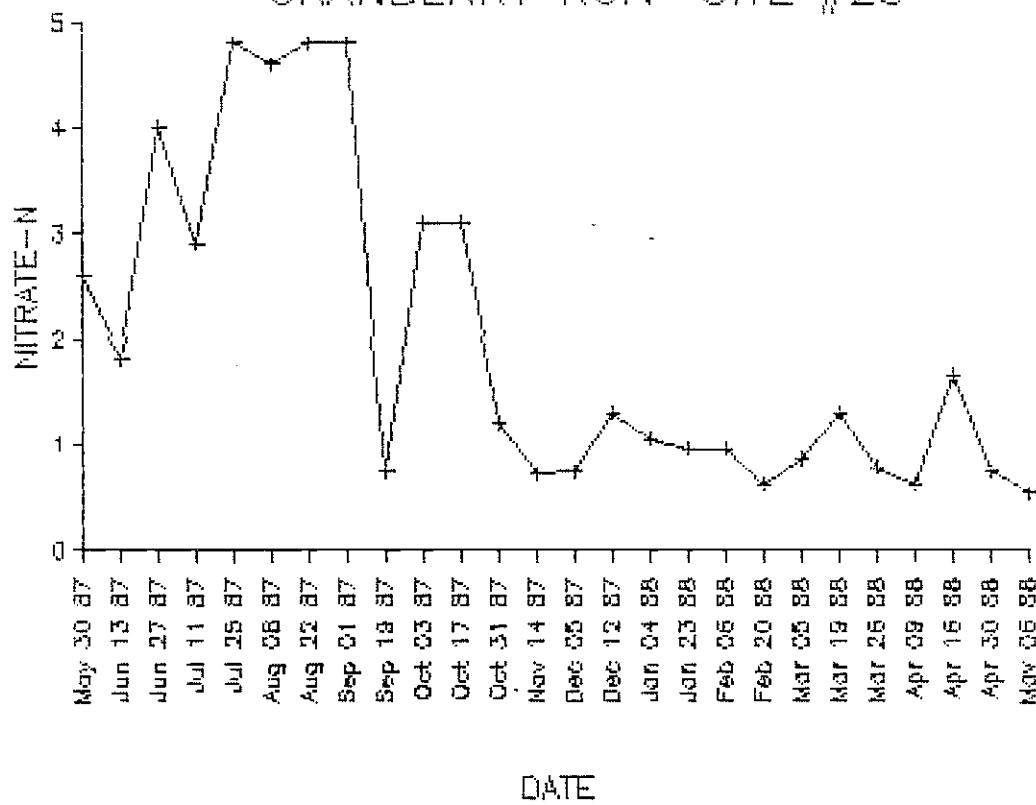
CRANBERRY RUN SITE #21



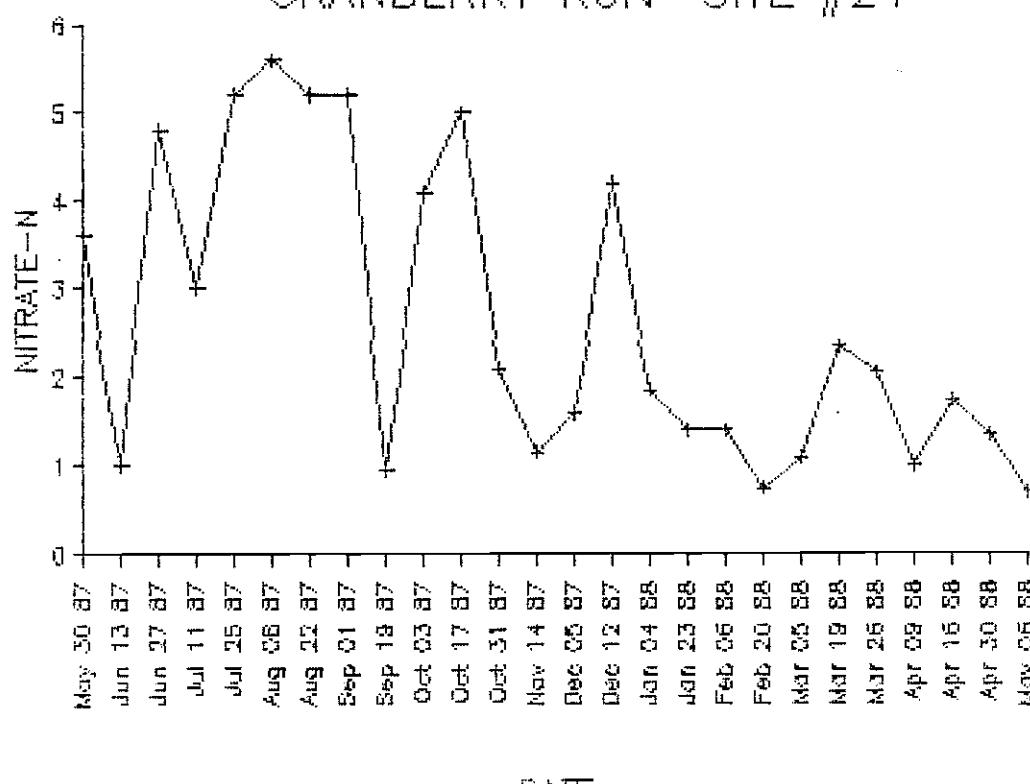
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23

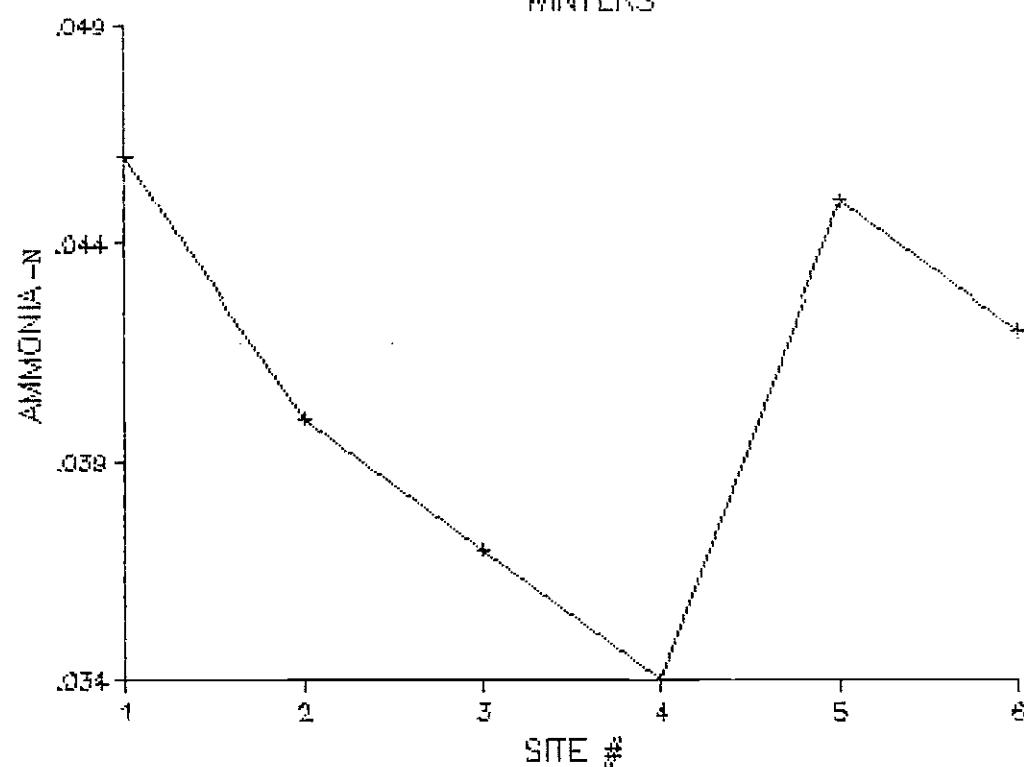


CRANBERRY RUN SITE #24

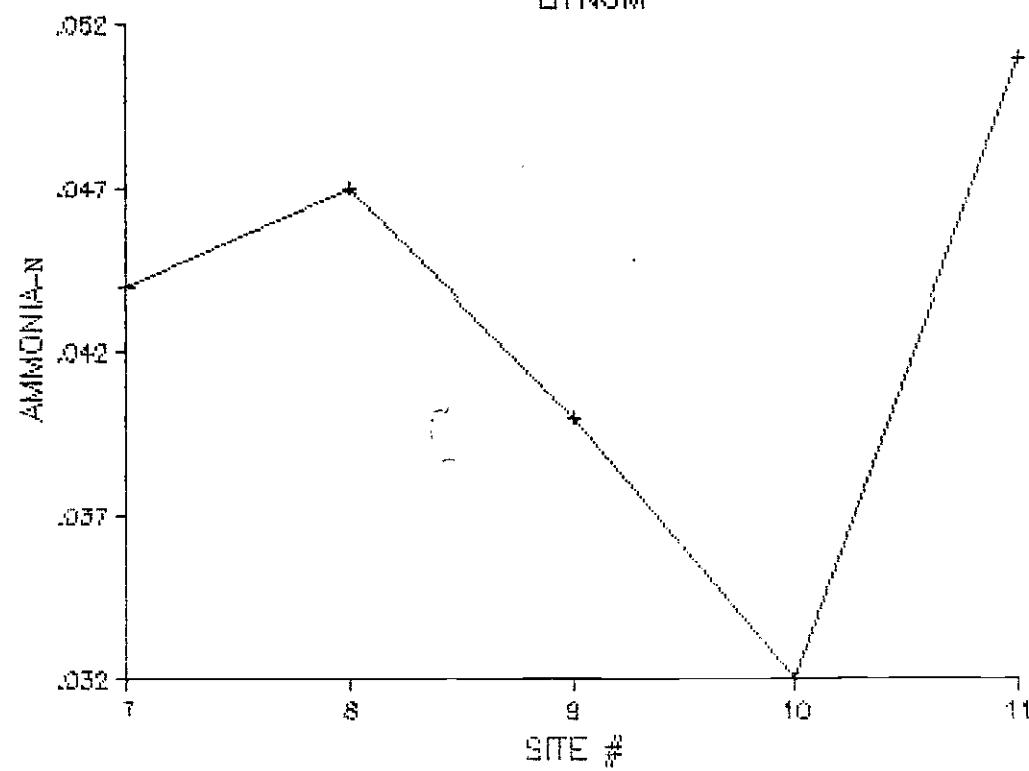


Ammonium-N
(mg/l.)

YEARLY AVERAGES
WINTERS

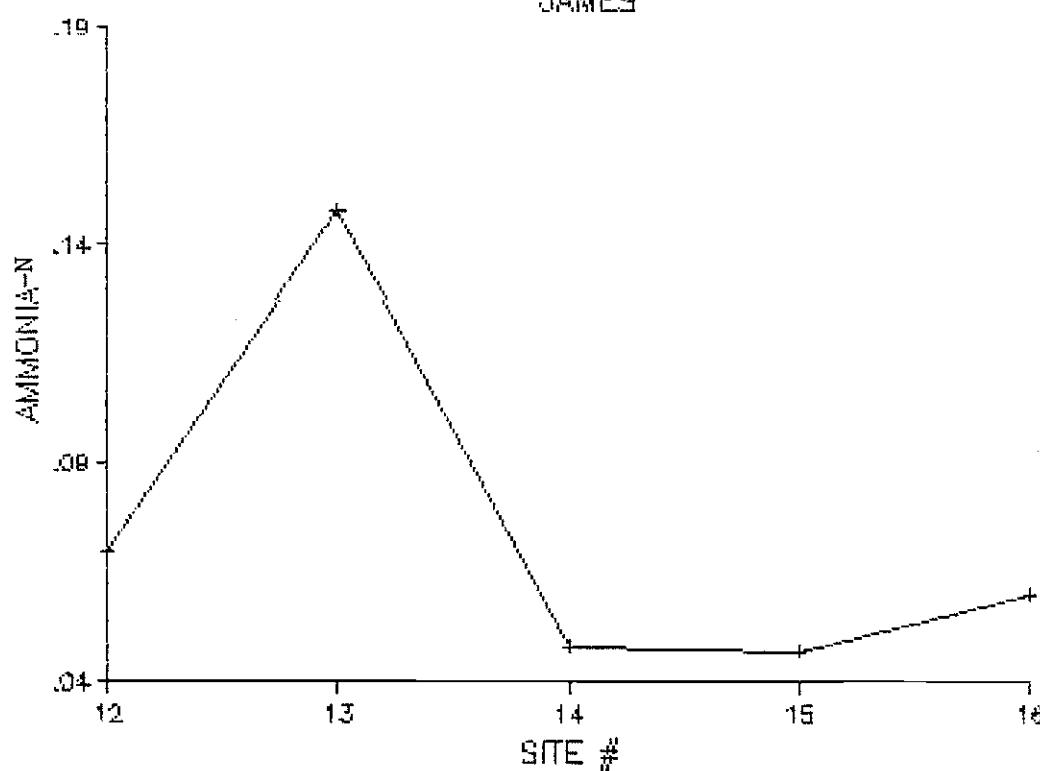


YEARLY AVERAGES
BYNUM



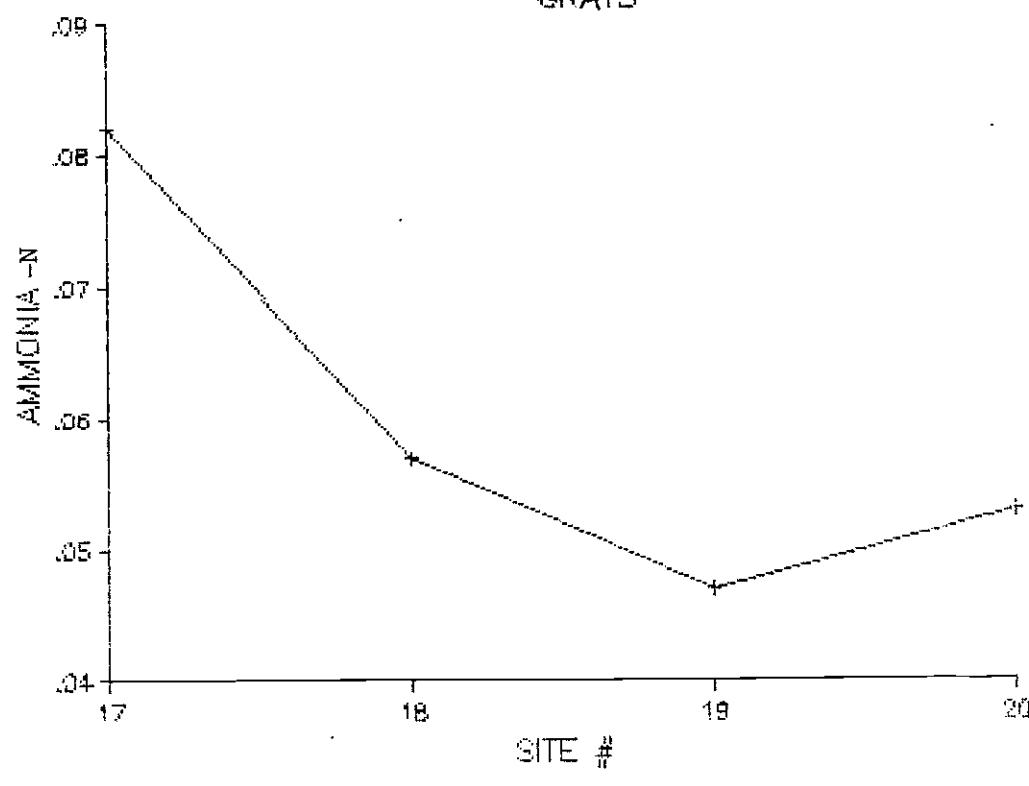
YEARLY AVERAGES

JAMES

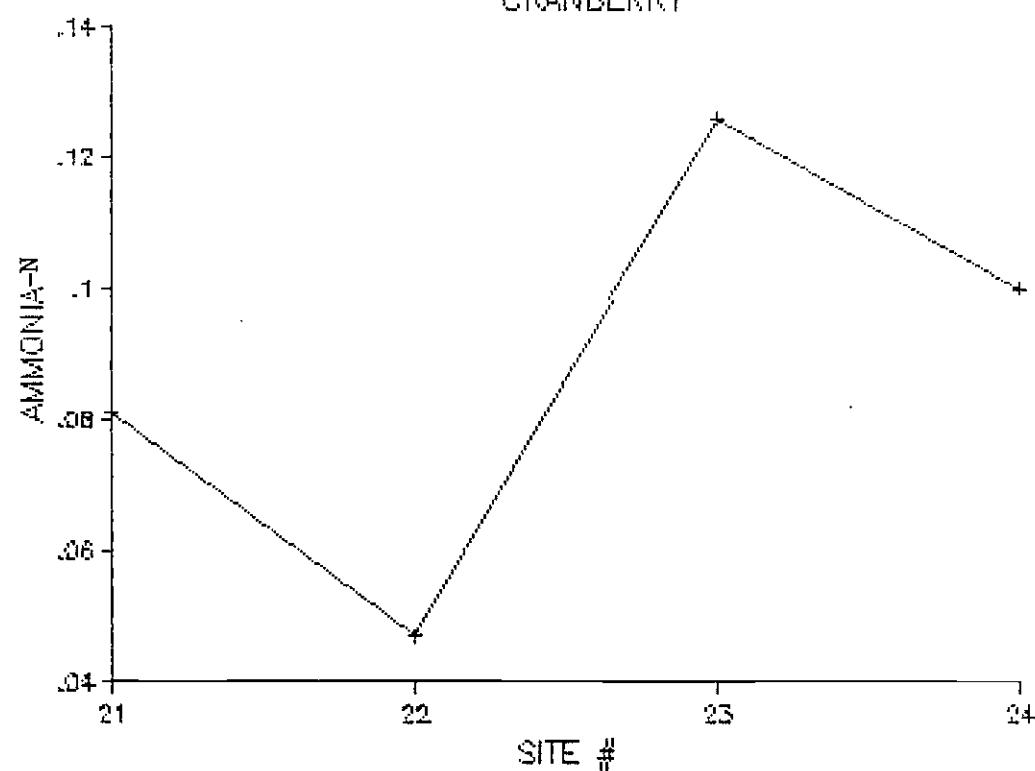


YEARLY AVERAGES

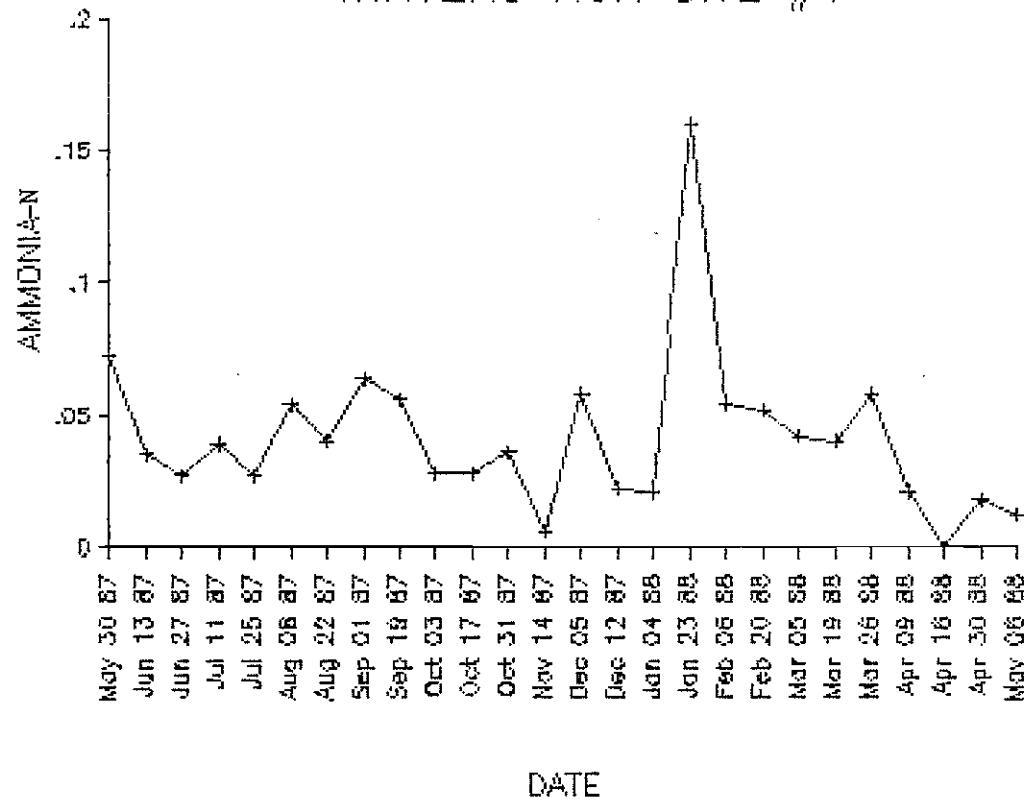
GRAYS



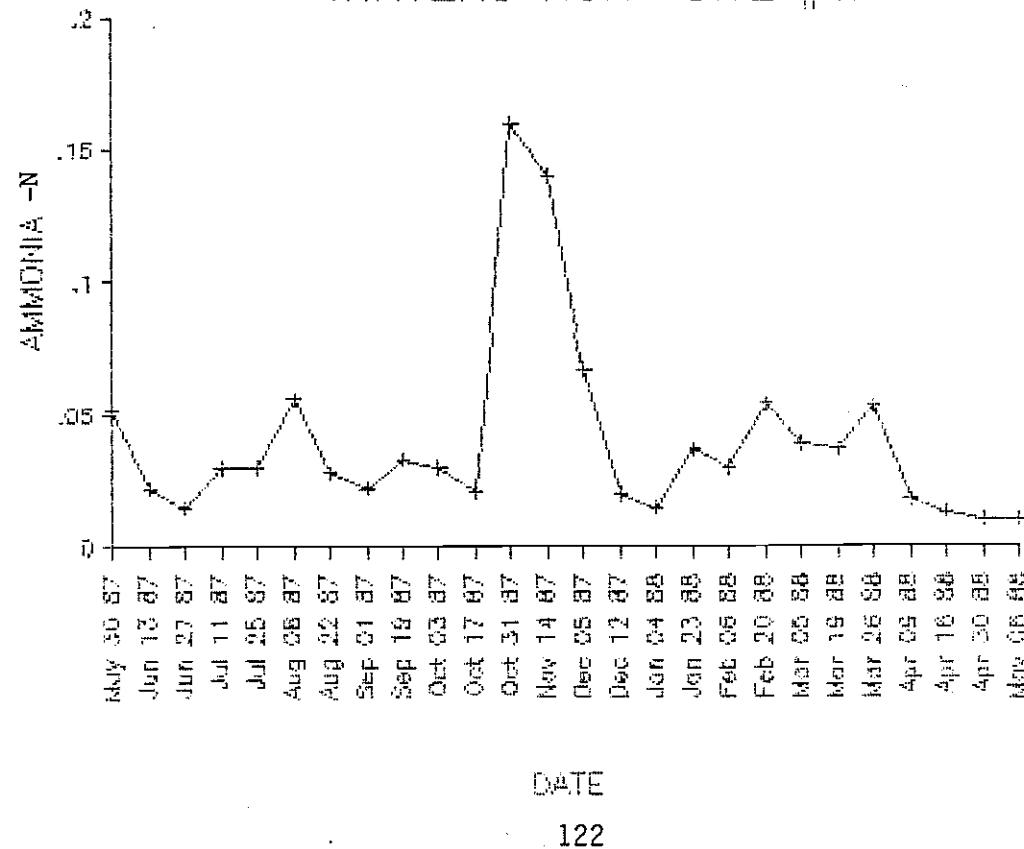
YEARLY AVERAGES
CRANBERRY



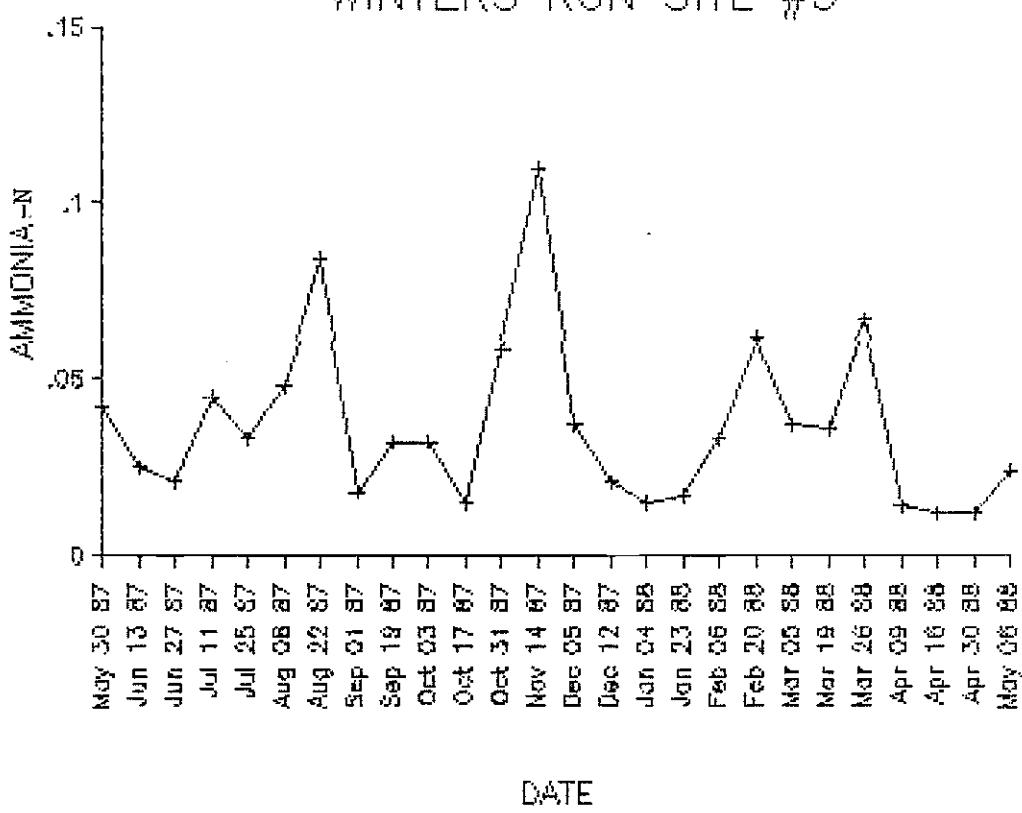
WINTERS RUN SITE #1



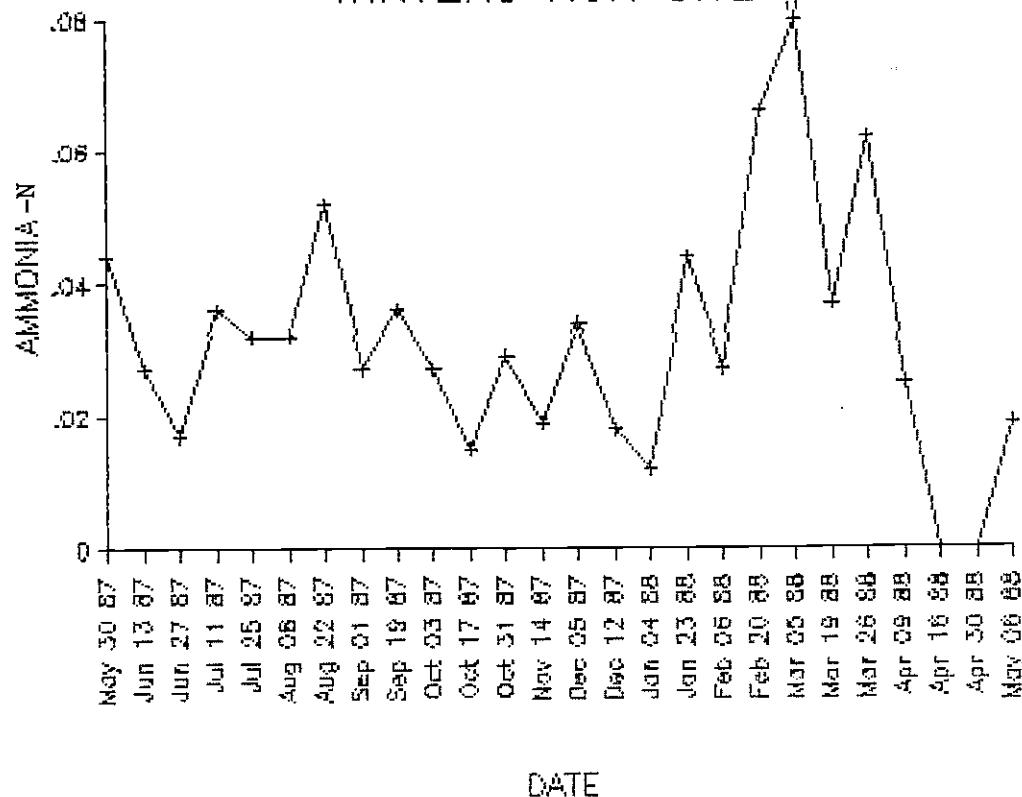
WINTERS RUN SITE #2



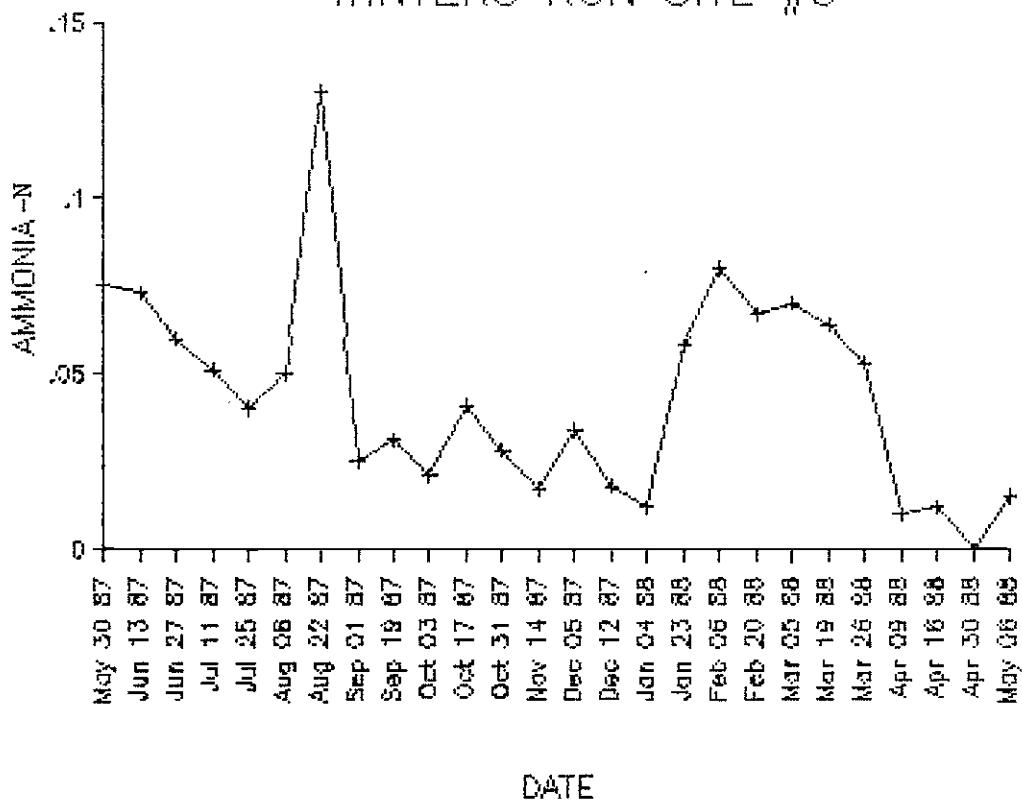
WINTERS RUN SITE #3



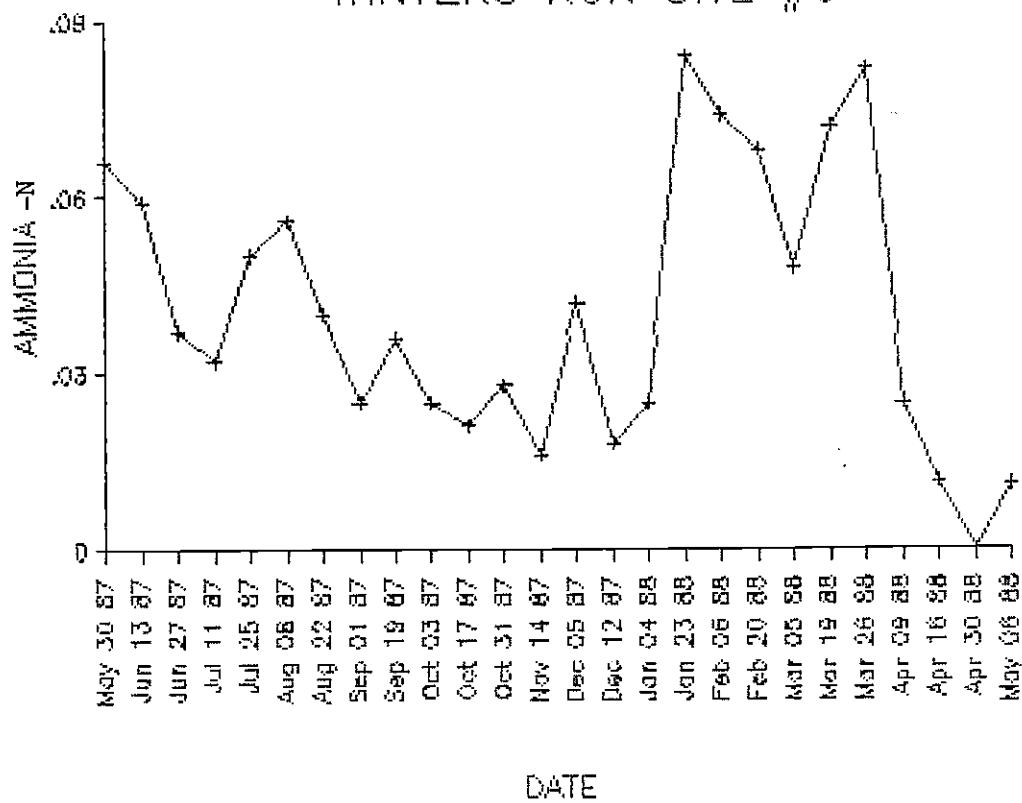
WINTERS RUN SITE #4



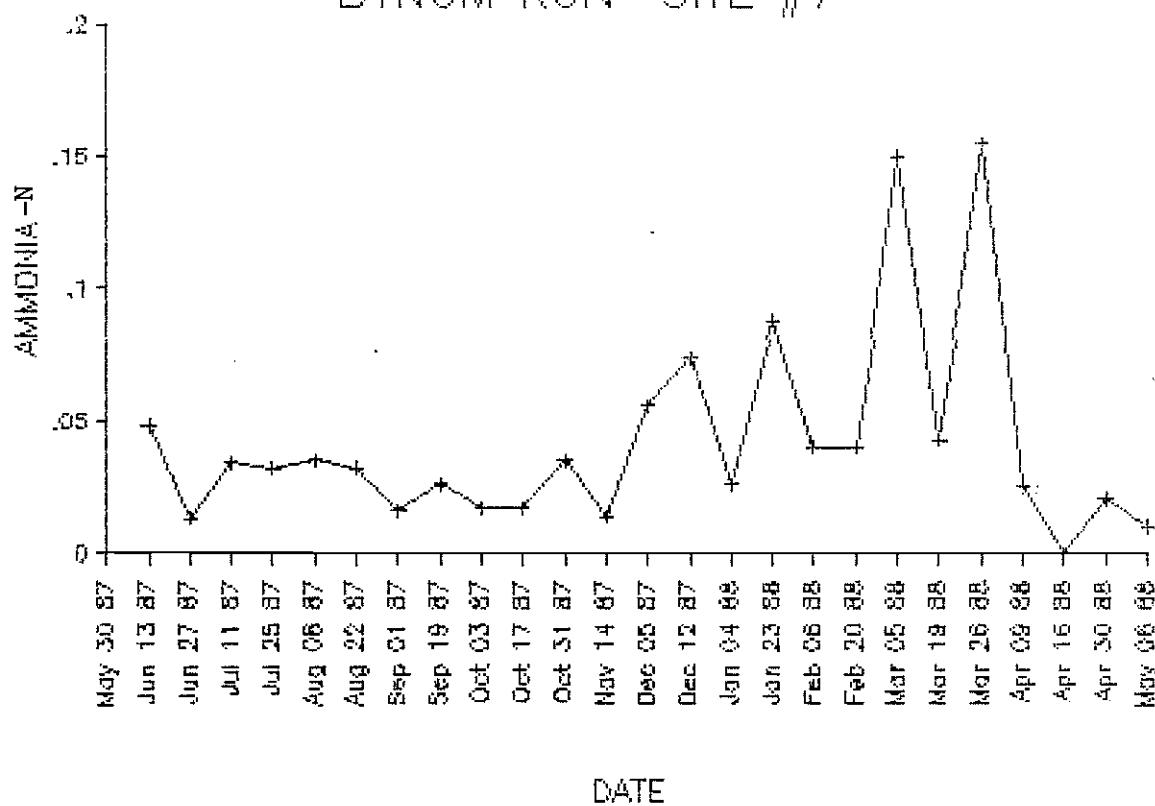
WINTERS RUN SITE #5



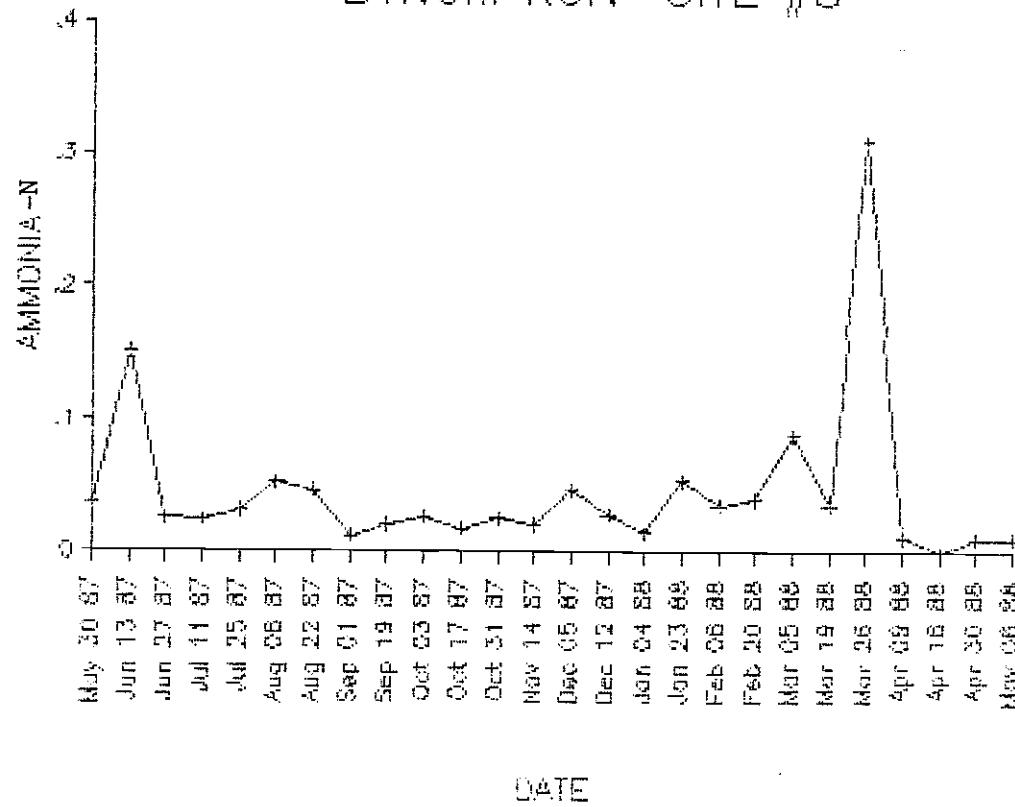
WINTERS RUN SITE #6



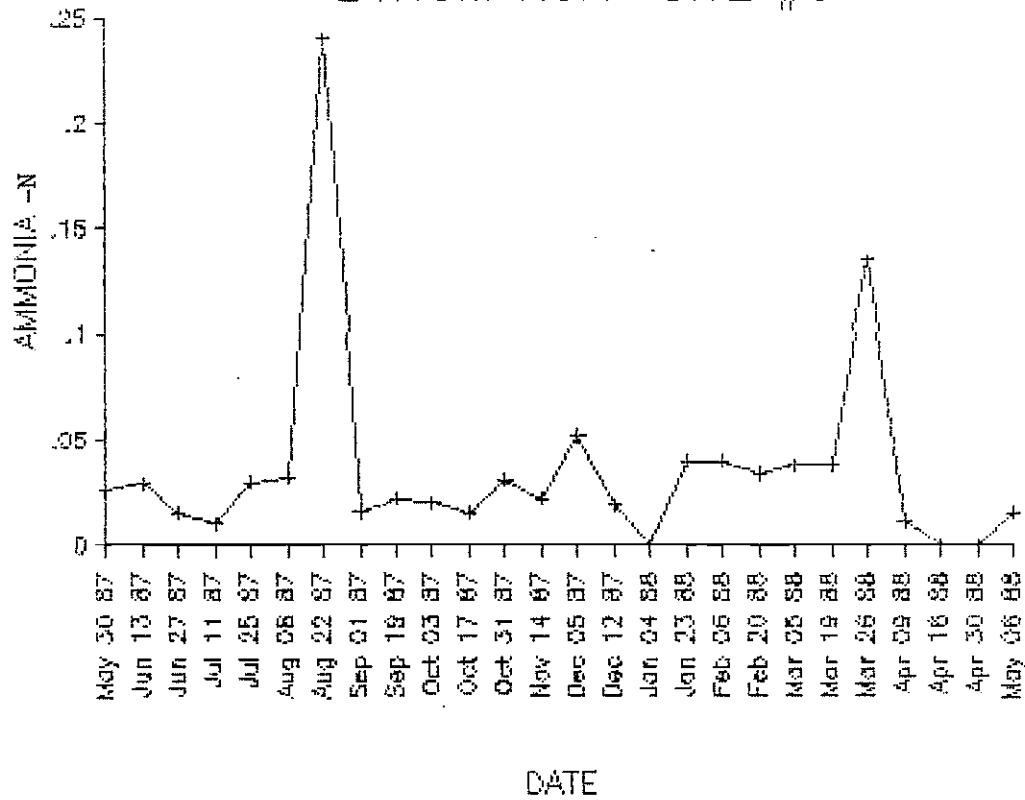
BYNUM RUN SITE #7



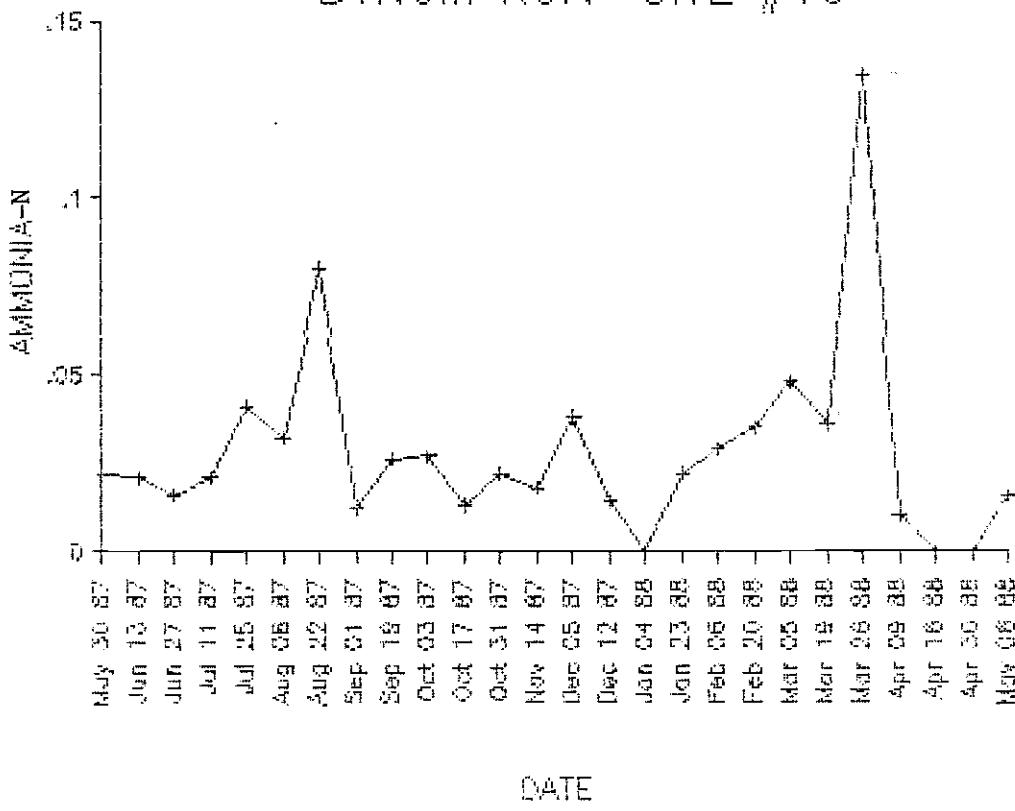
BYNUM RUN SITE #8



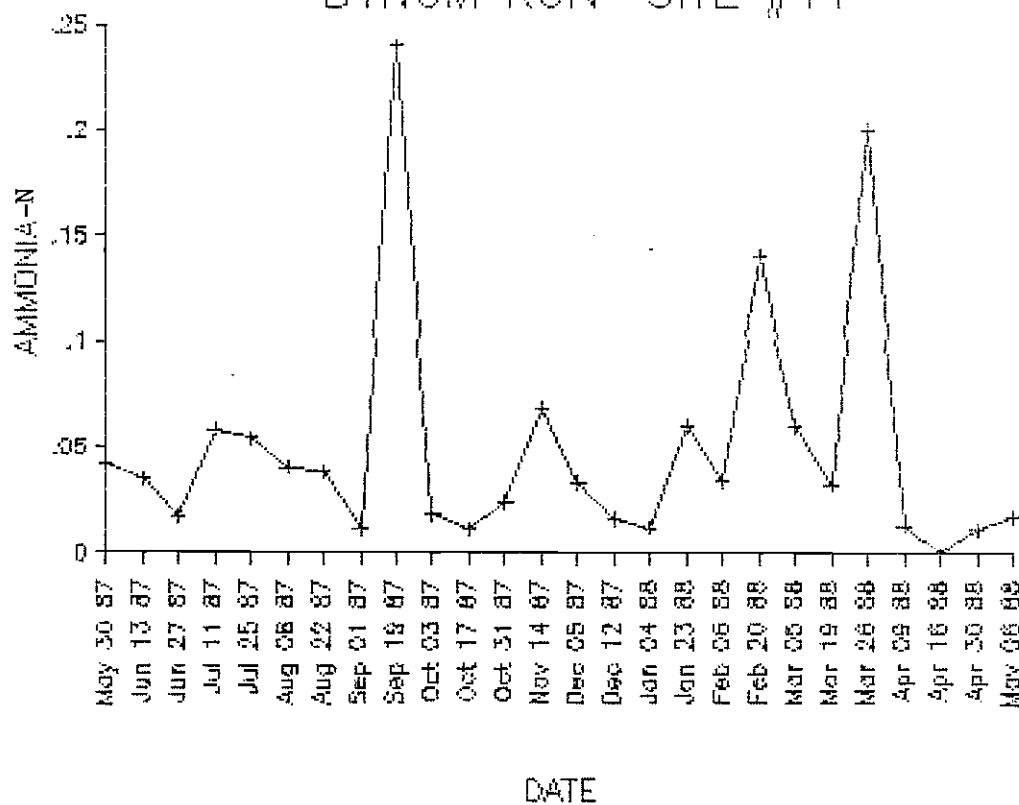
BYNUM RUN SITE #9



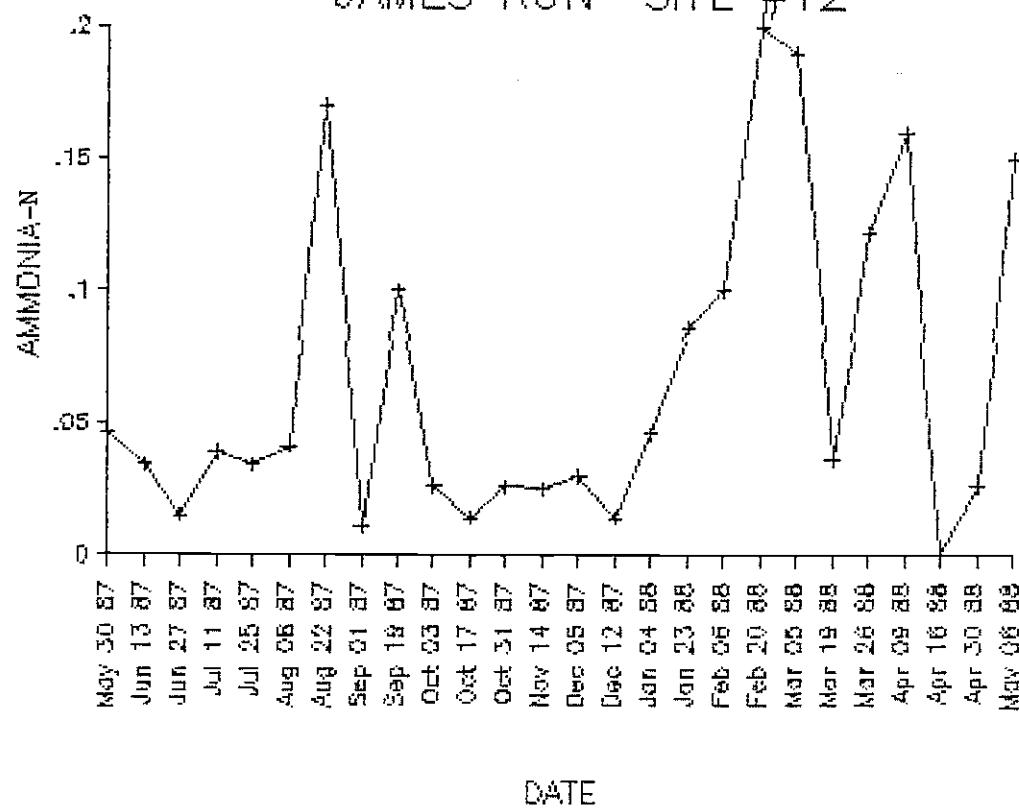
BYNUM RUN SITE #10



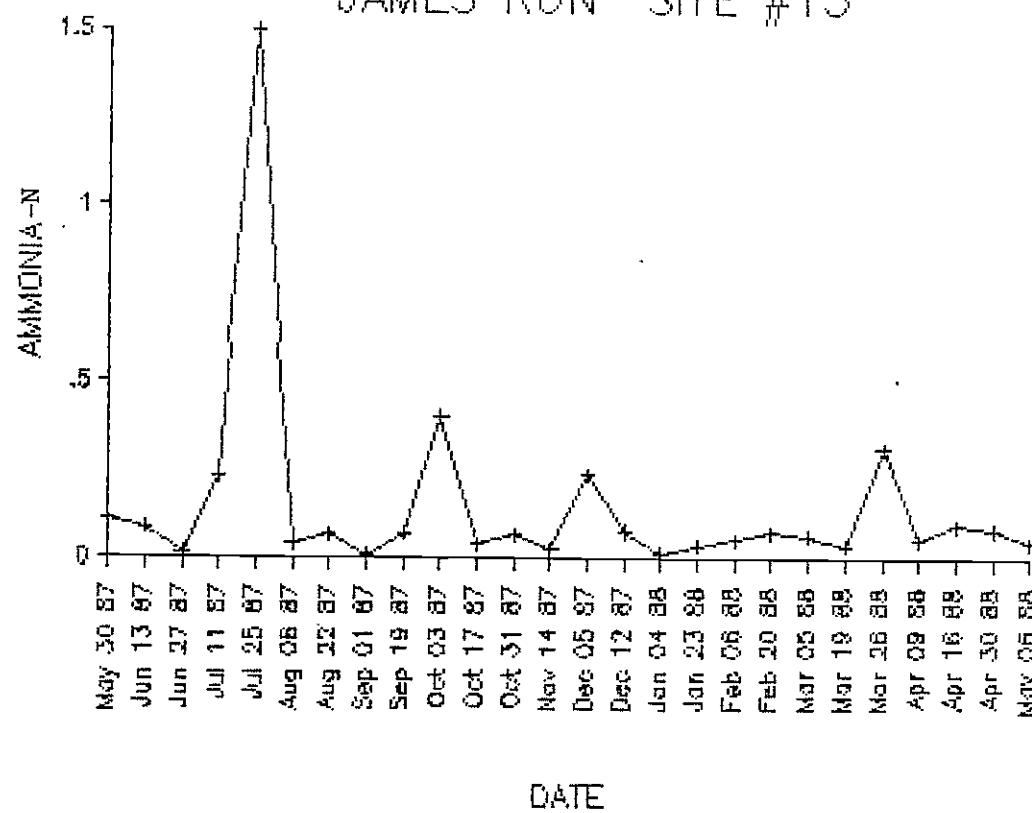
BYNUM RUN SITE #11



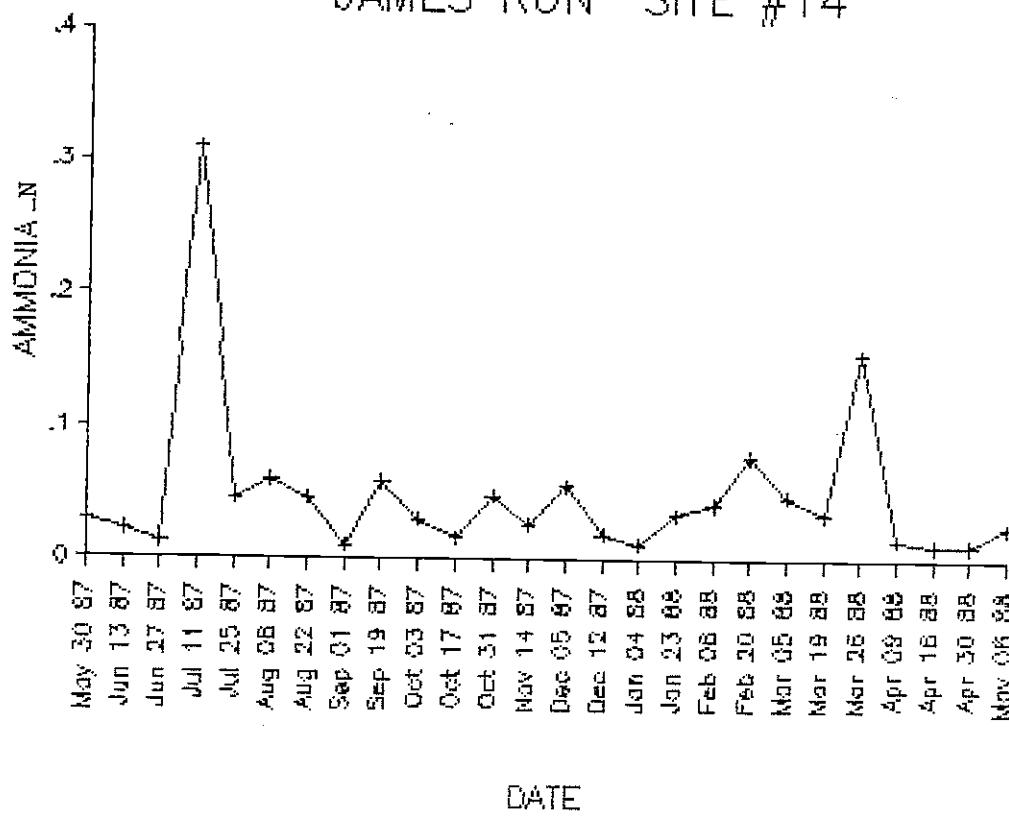
JAMES RUN SITE #12



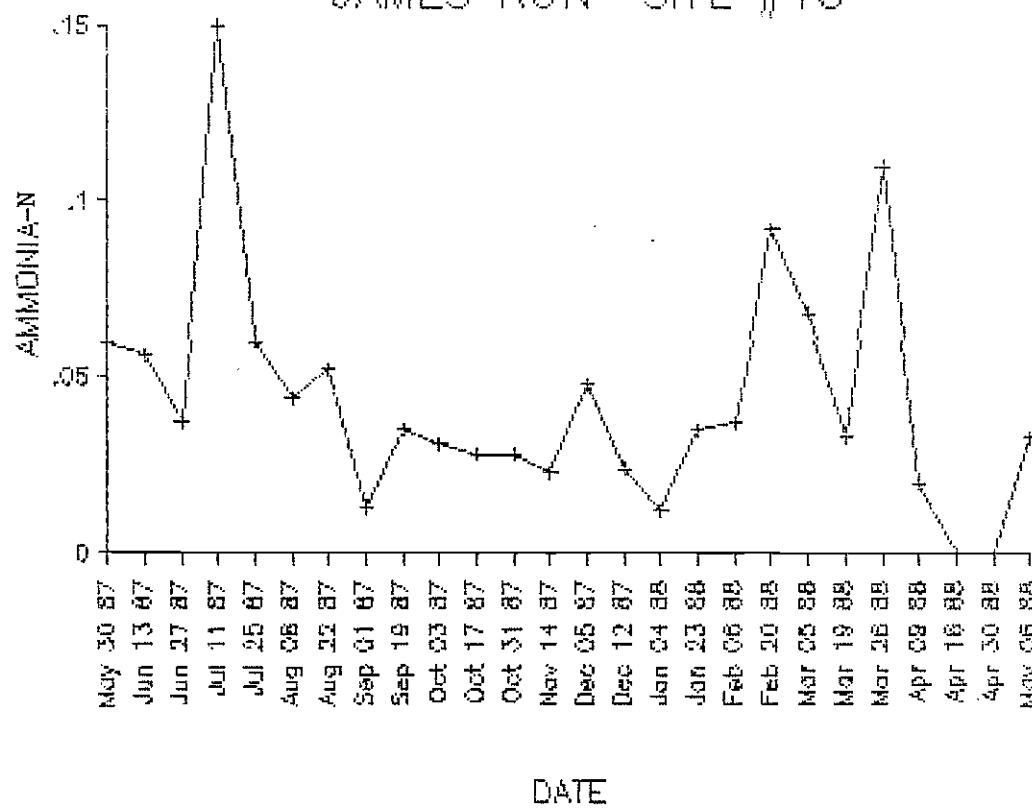
JAMES RUN SITE #13



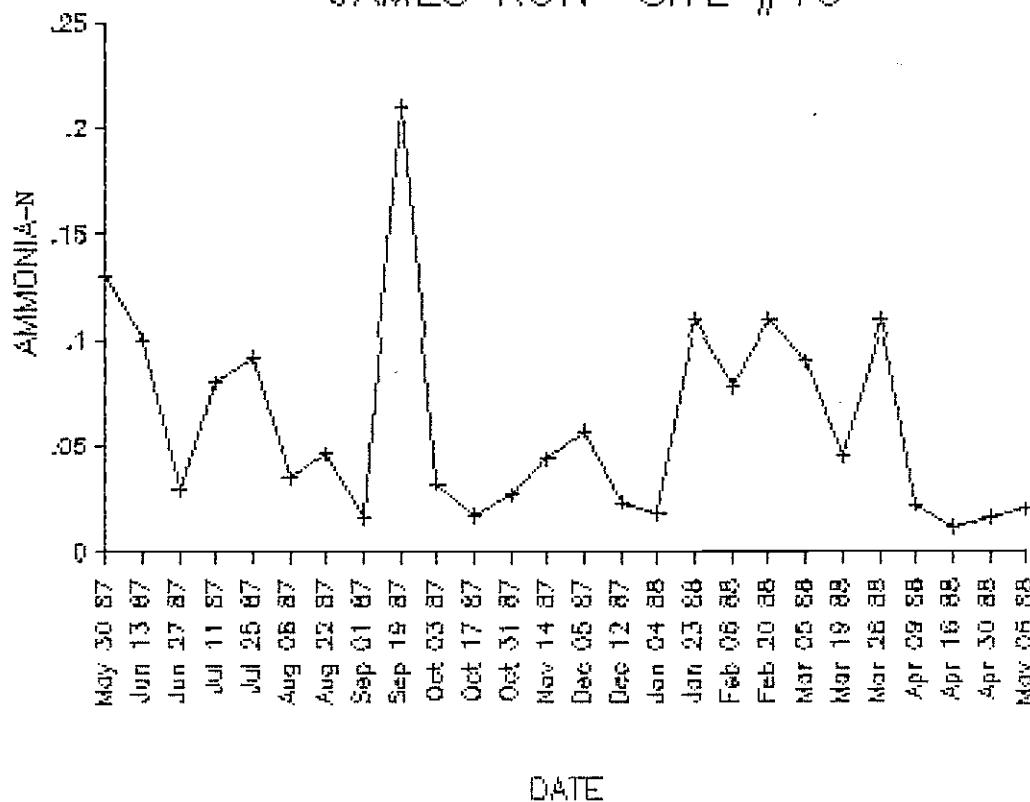
JAMES RUN SITE #14



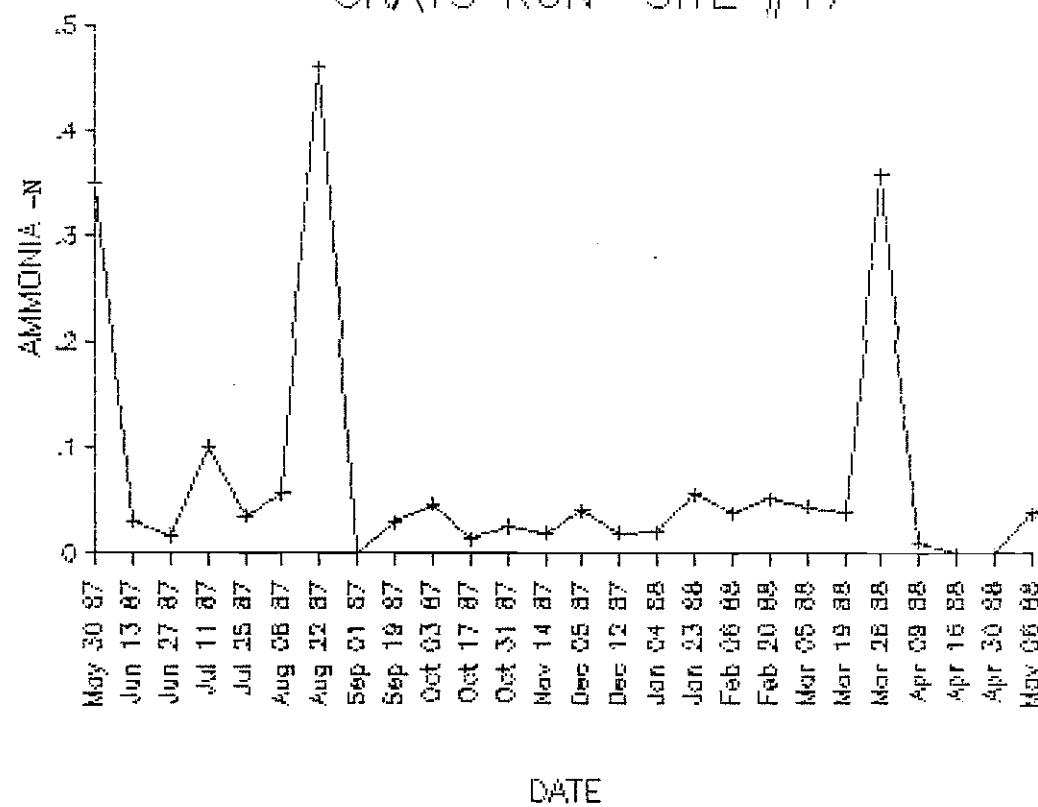
JAMES RUN SITE #15



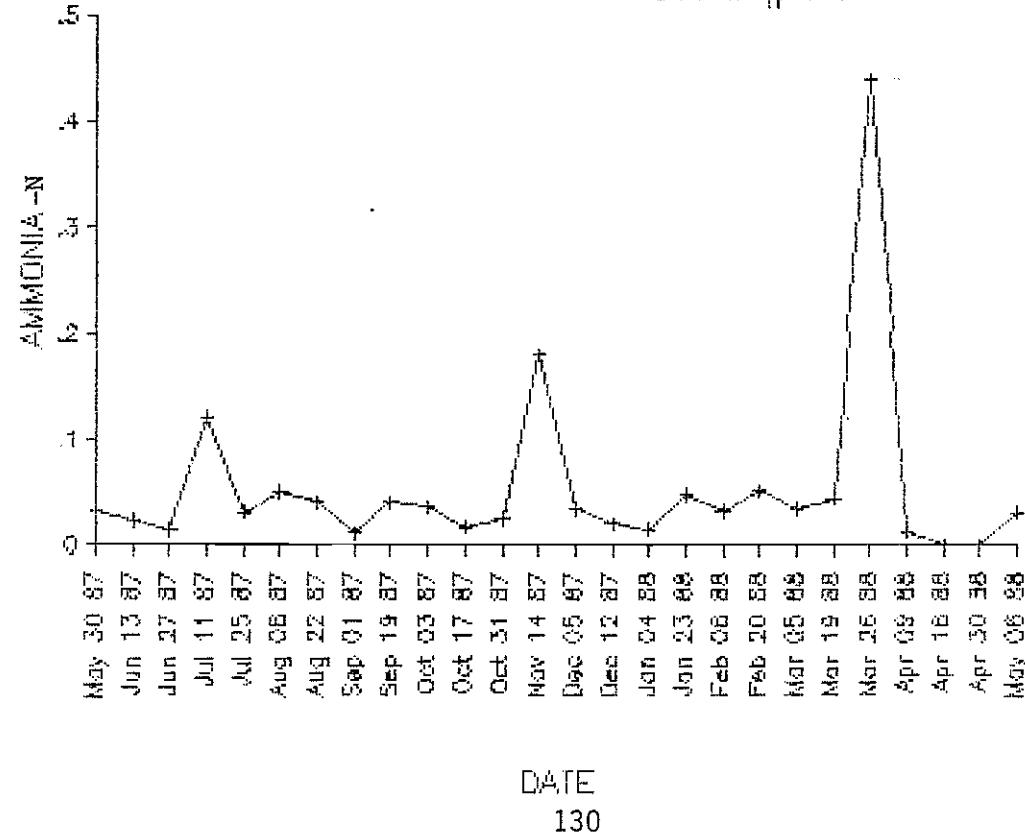
JAMES RUN SITE #15



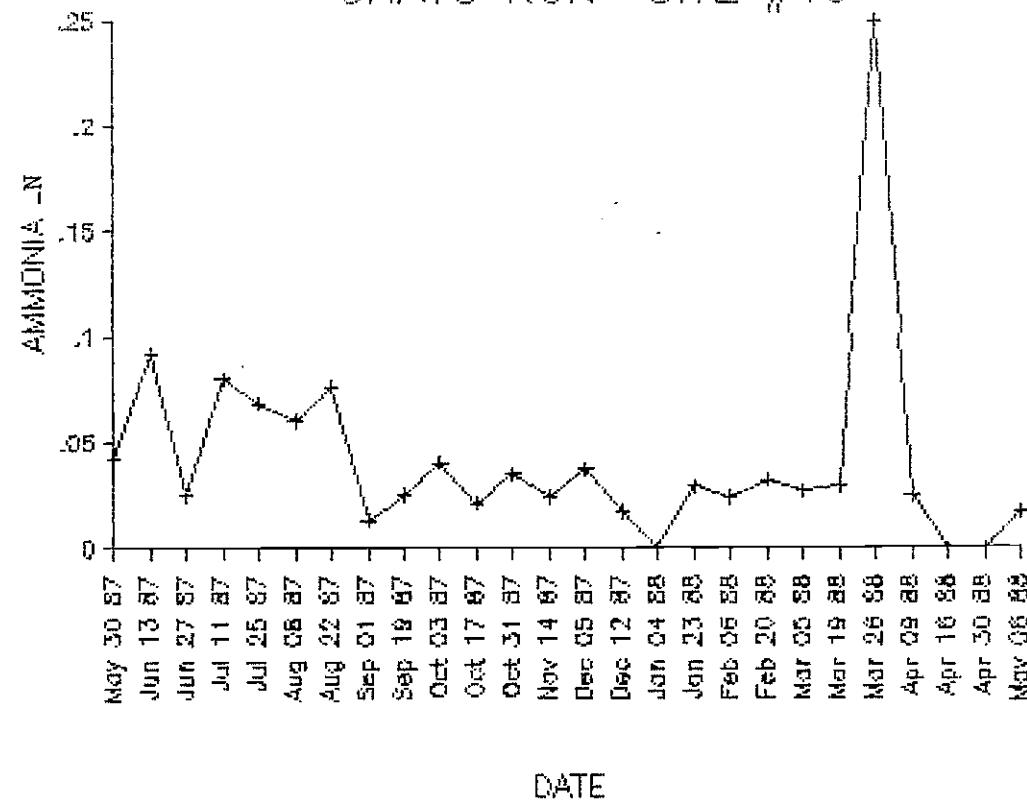
GRAYS RUN SITE #17



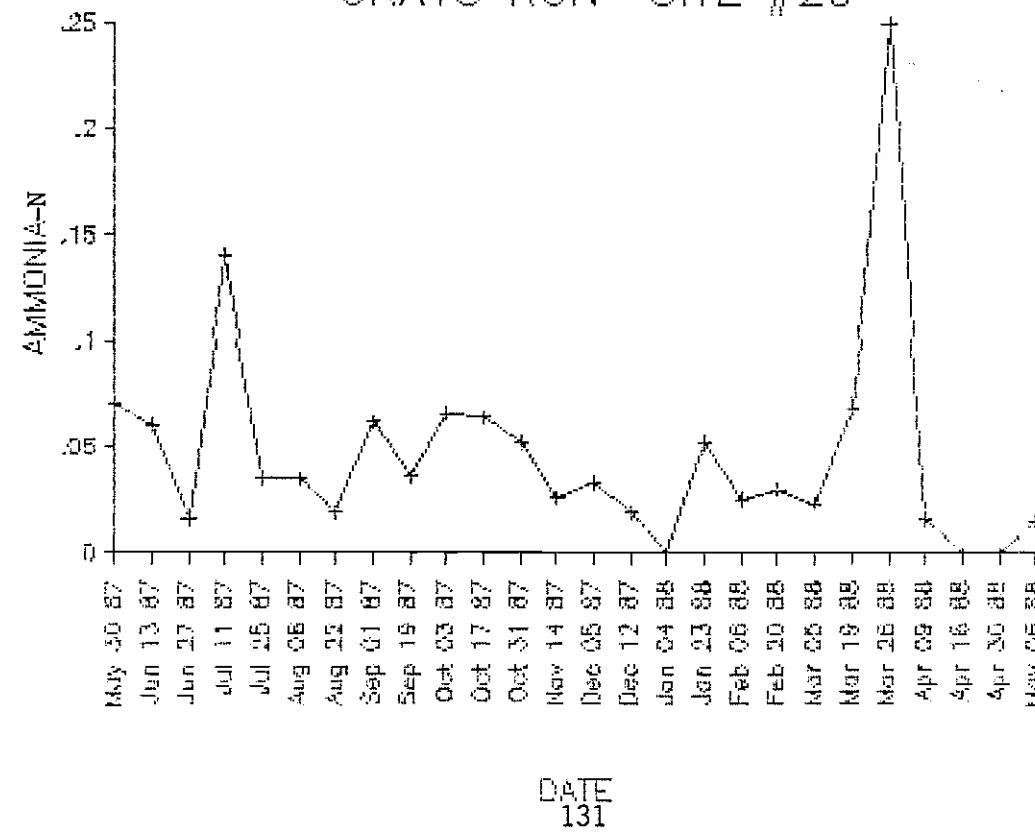
GRAYS RUN SITE #18



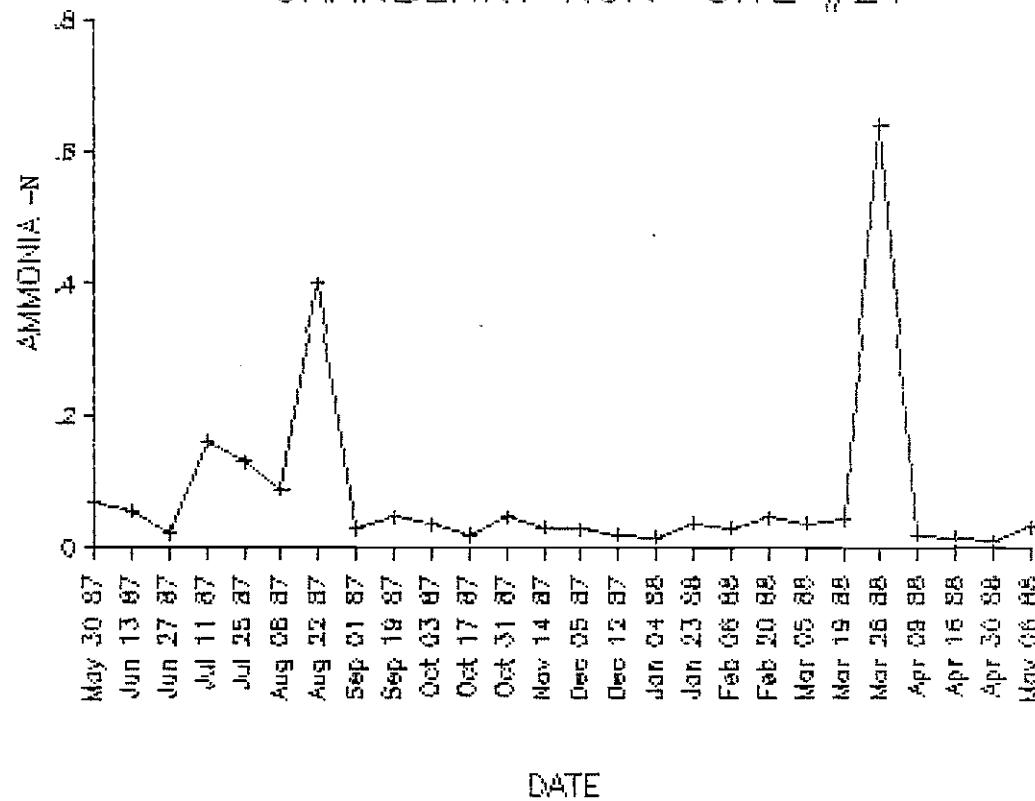
GRAYS RUN SITE #19



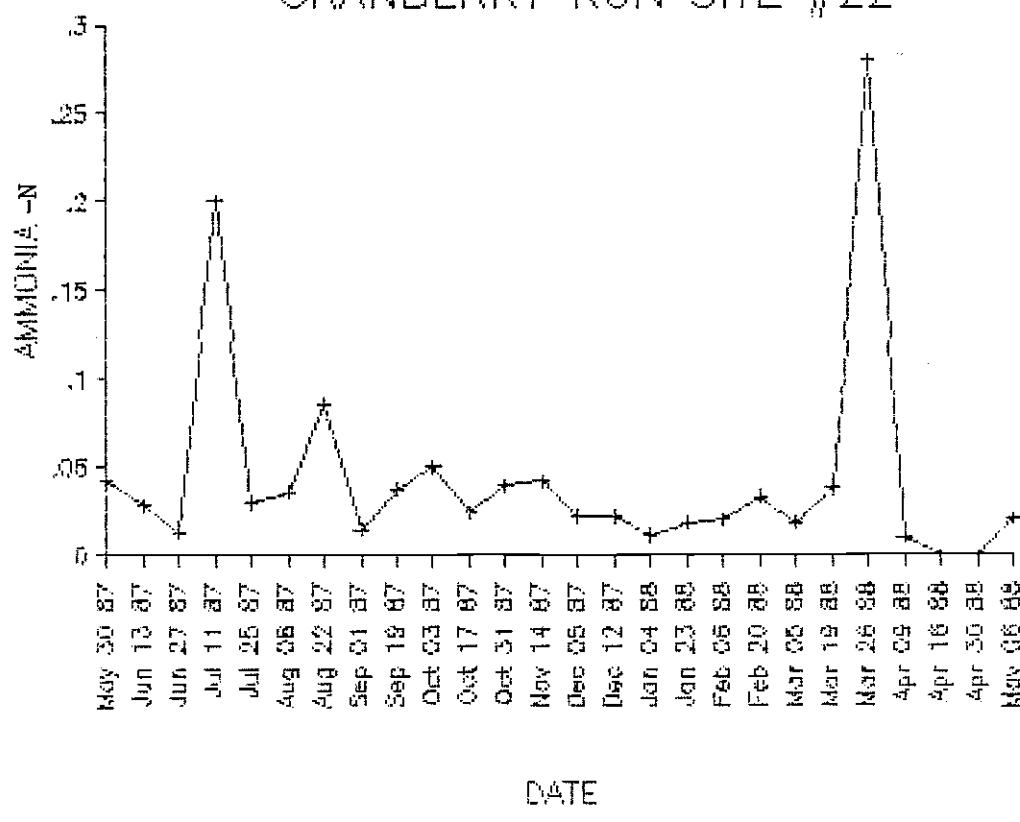
GRAYS RUN SITE #20



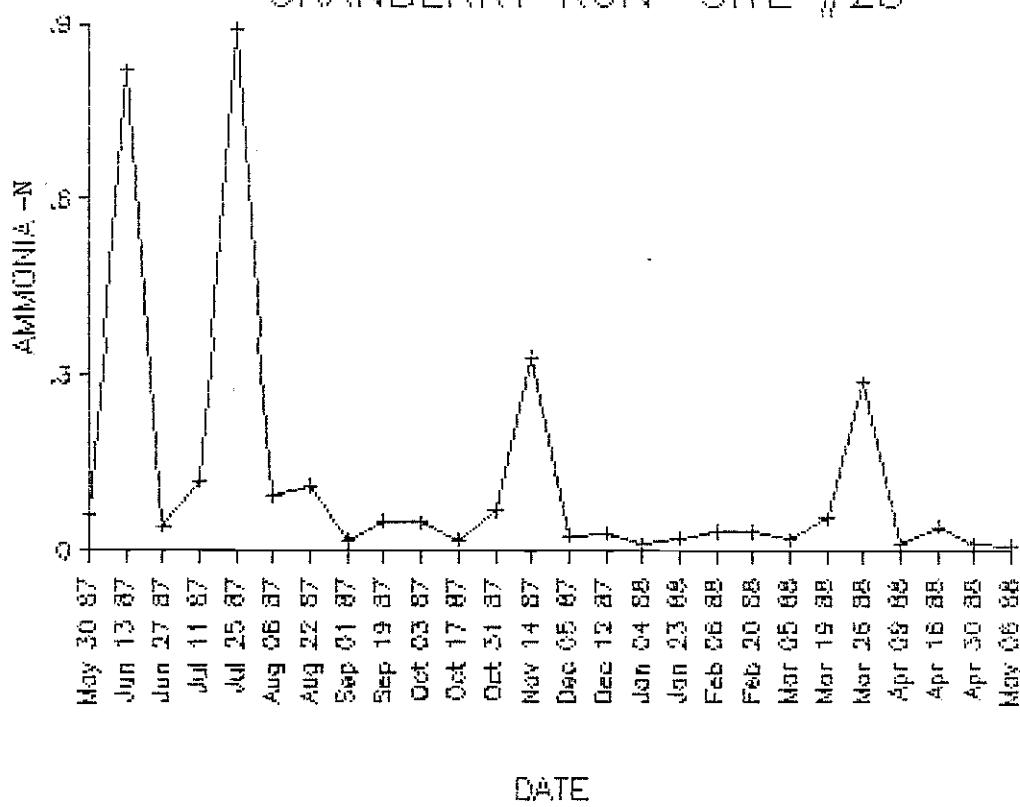
CRANBERRY RUN SITE #21



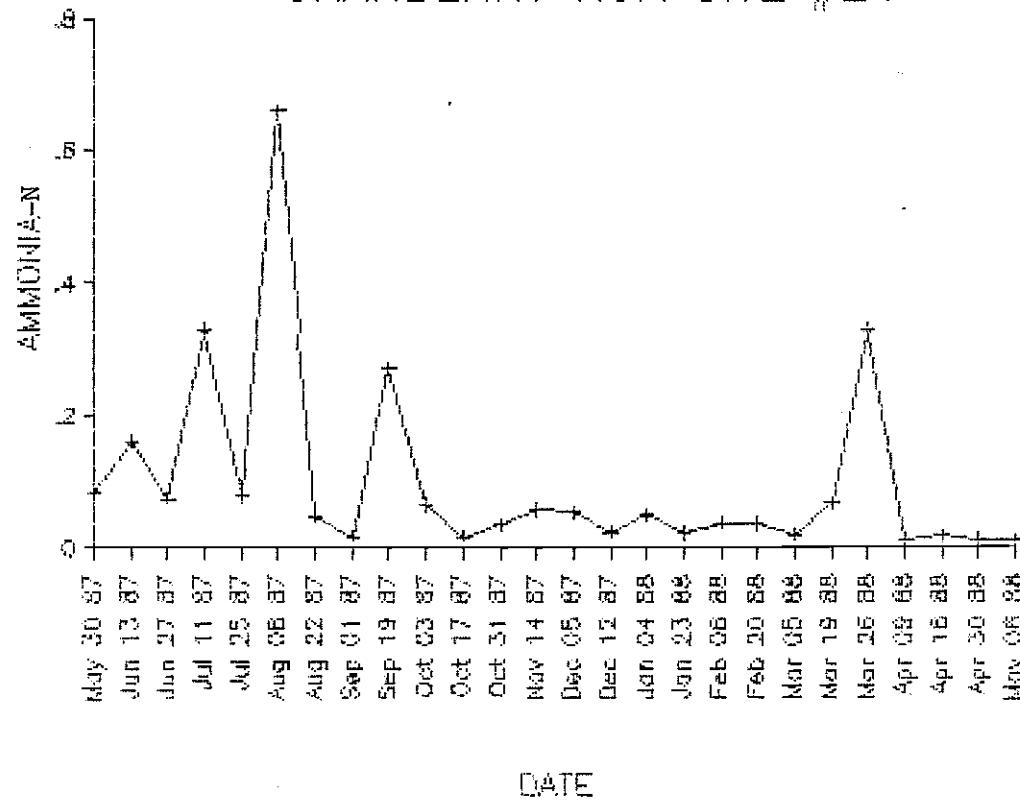
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23

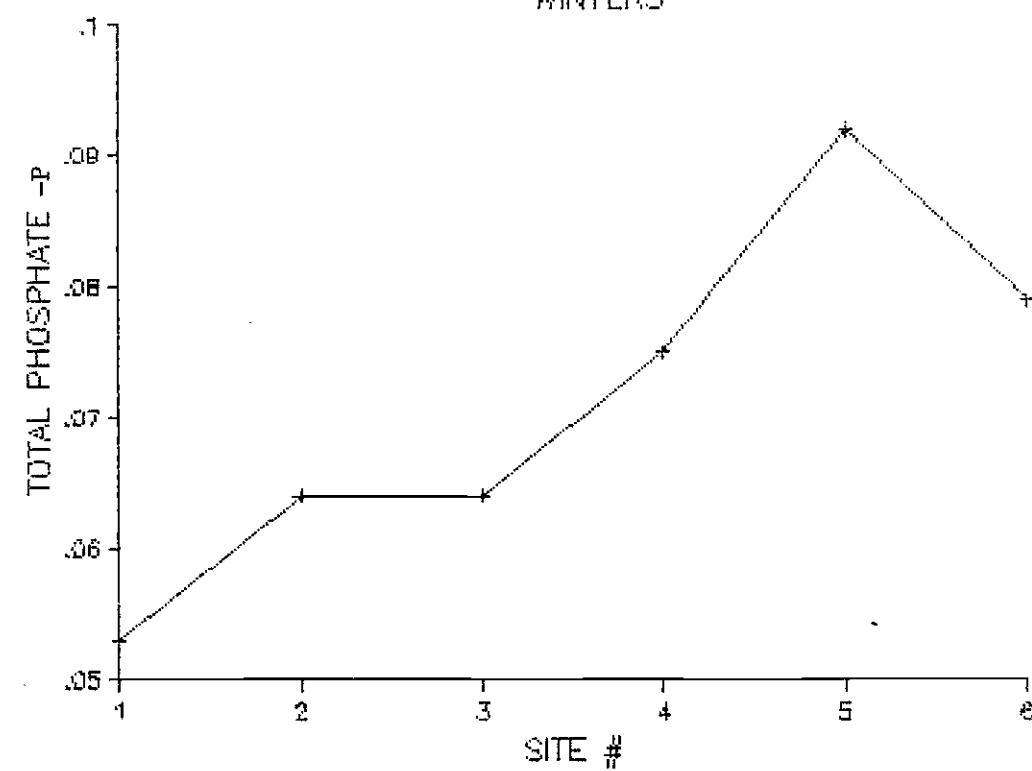


CRANBERRY RUN SITE #24

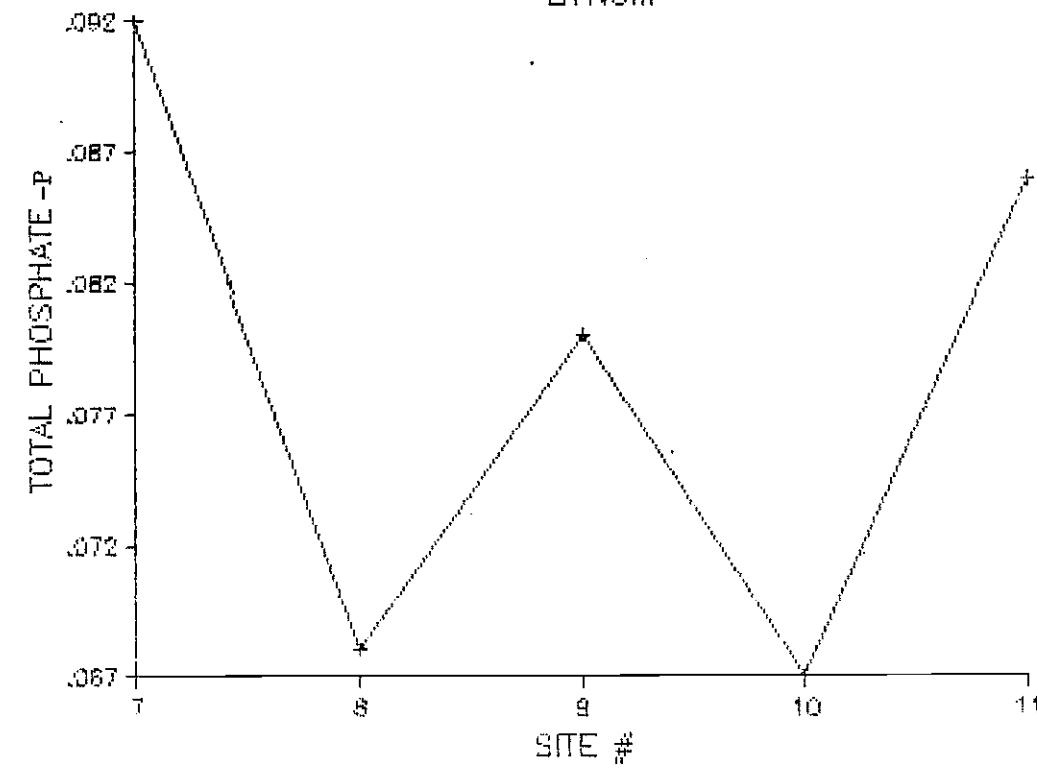


Total Phosphate-P
(mg/l)

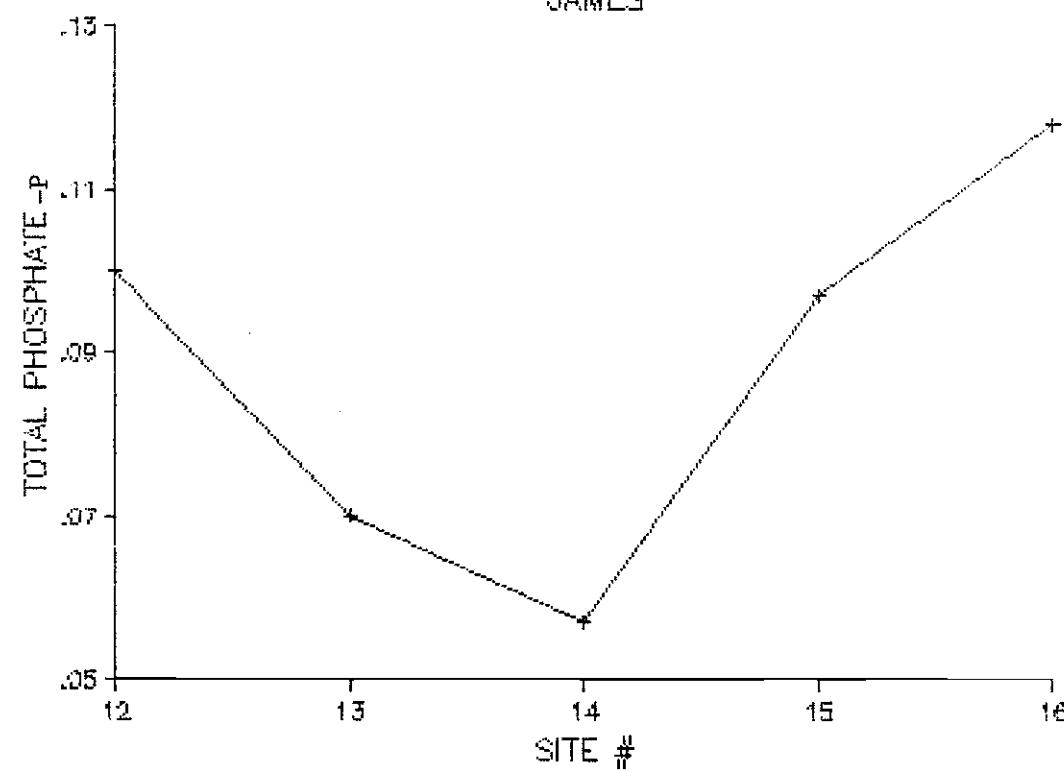
YEARLY AVERAGES
WINTERS



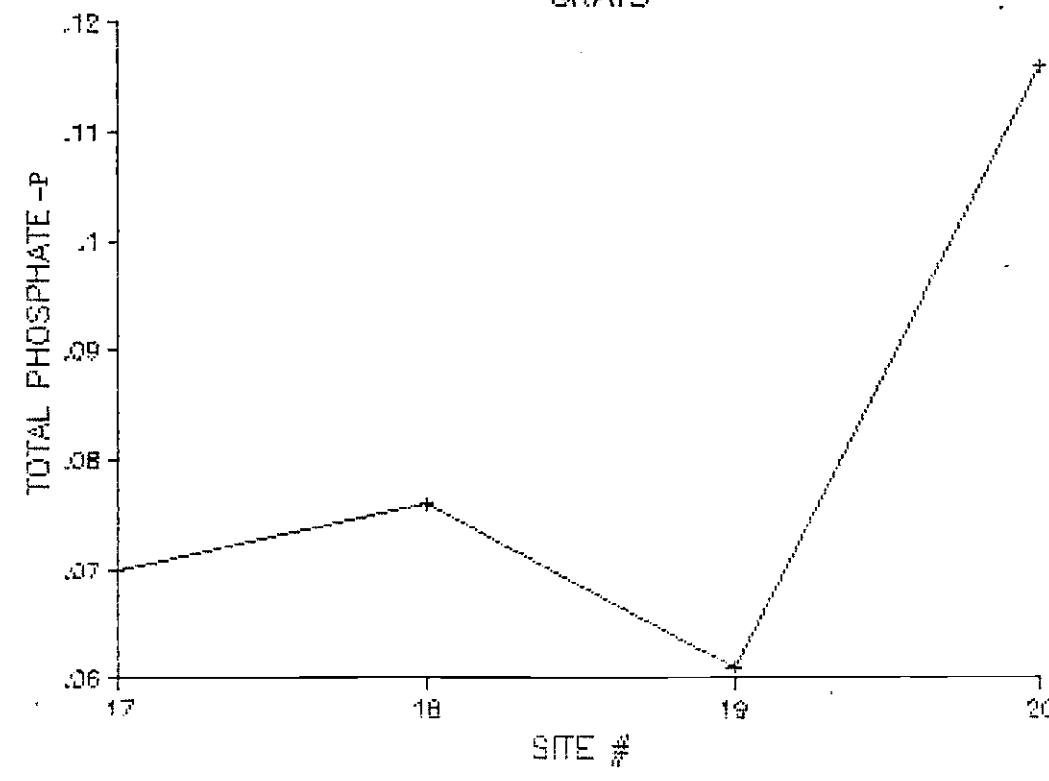
YEARLY AVERAGES
BYNUM



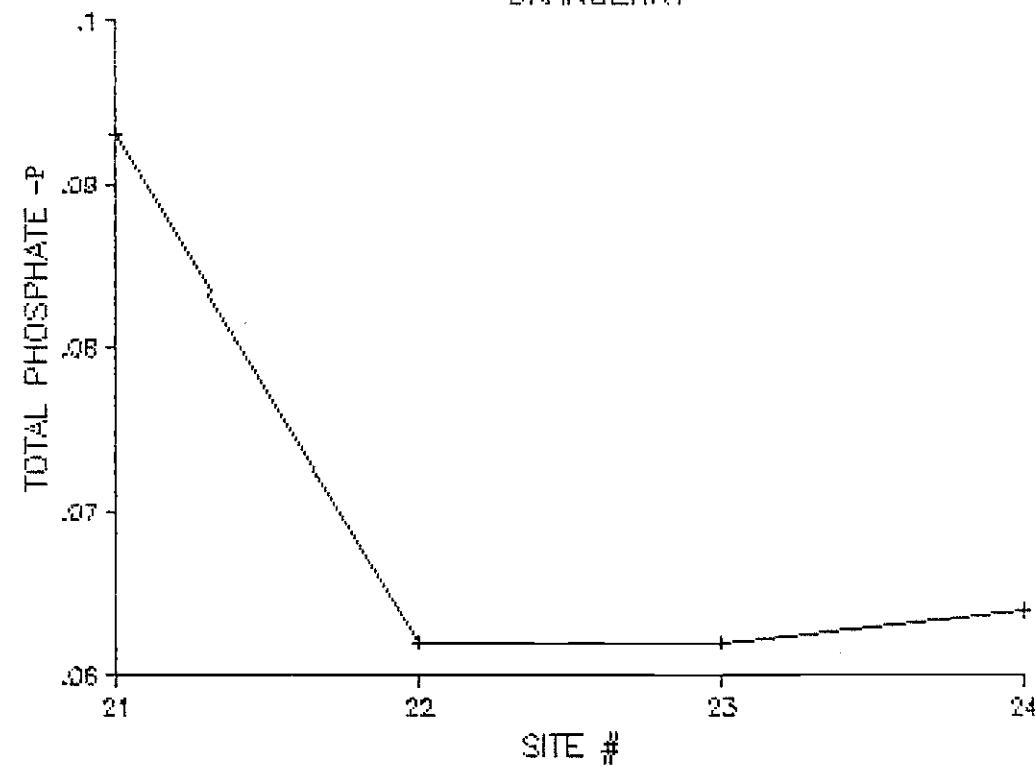
YEARLY AVERAGES
JAMES



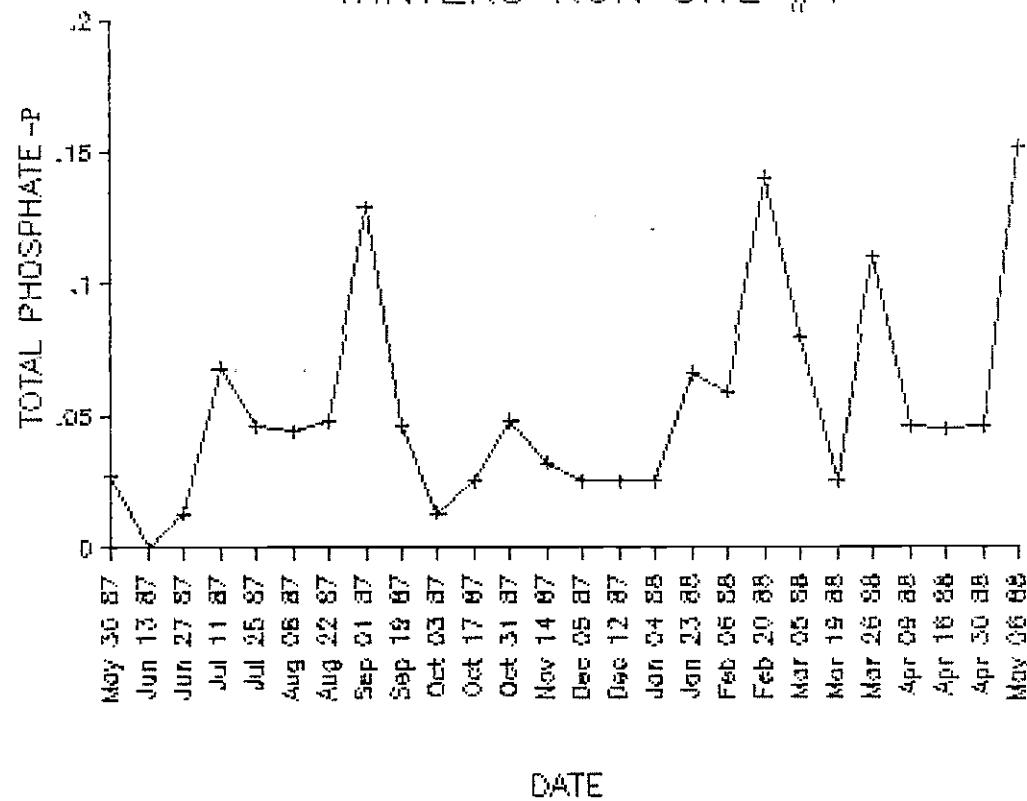
YEARLY AVERAGES
GRAYS



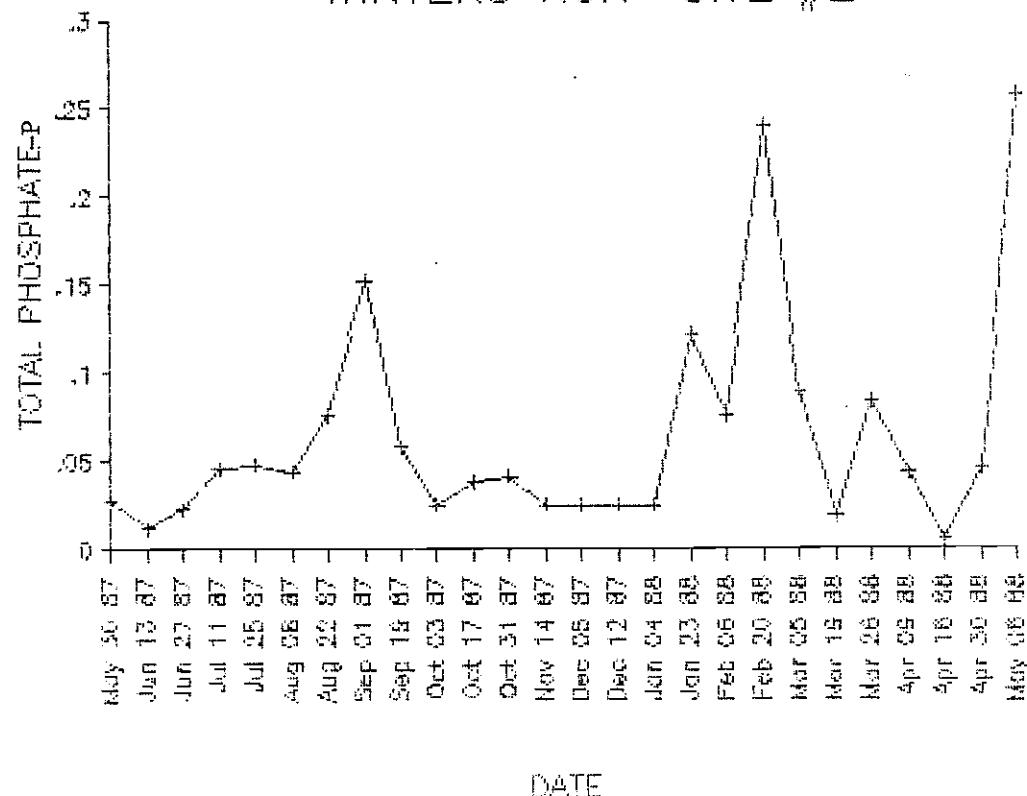
YEARLY AVERAGES
CRANBERRY



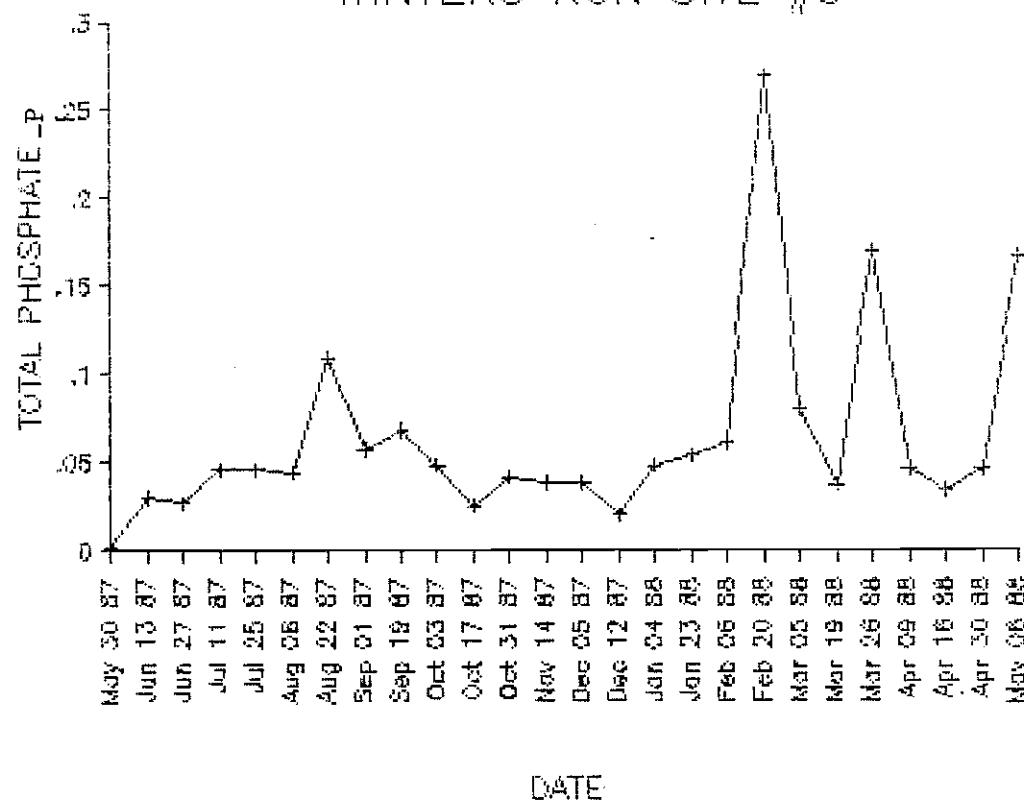
WINTERS RUN SITE #1



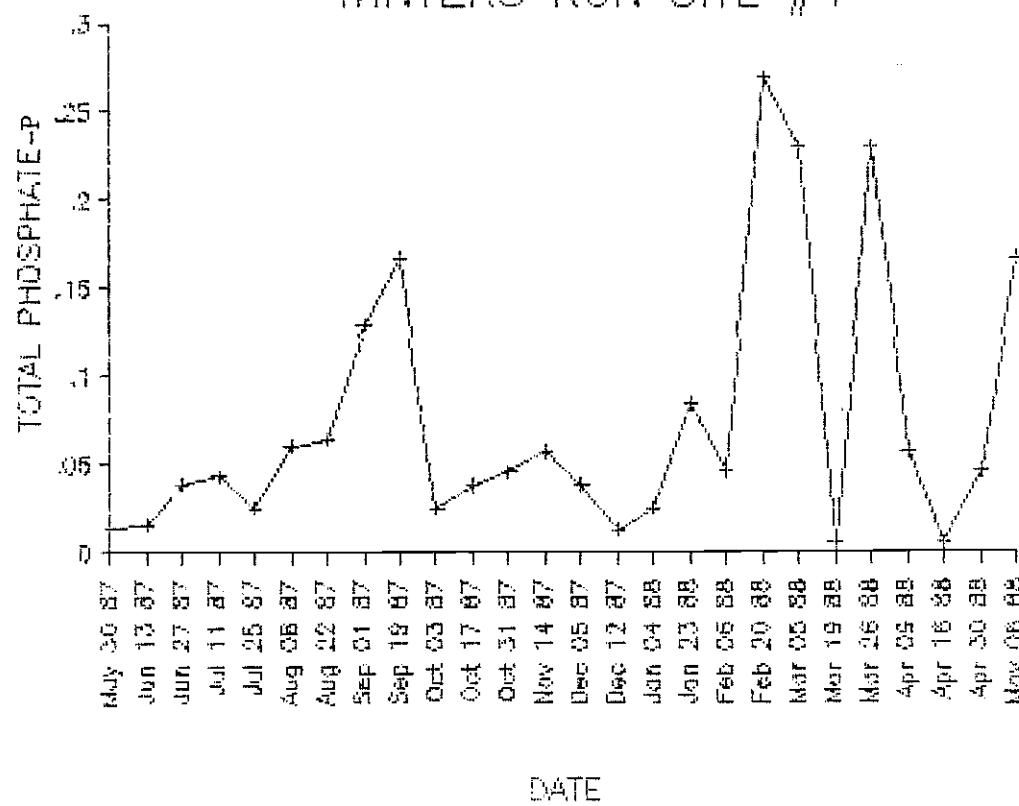
WINTERS RUN SITE #2



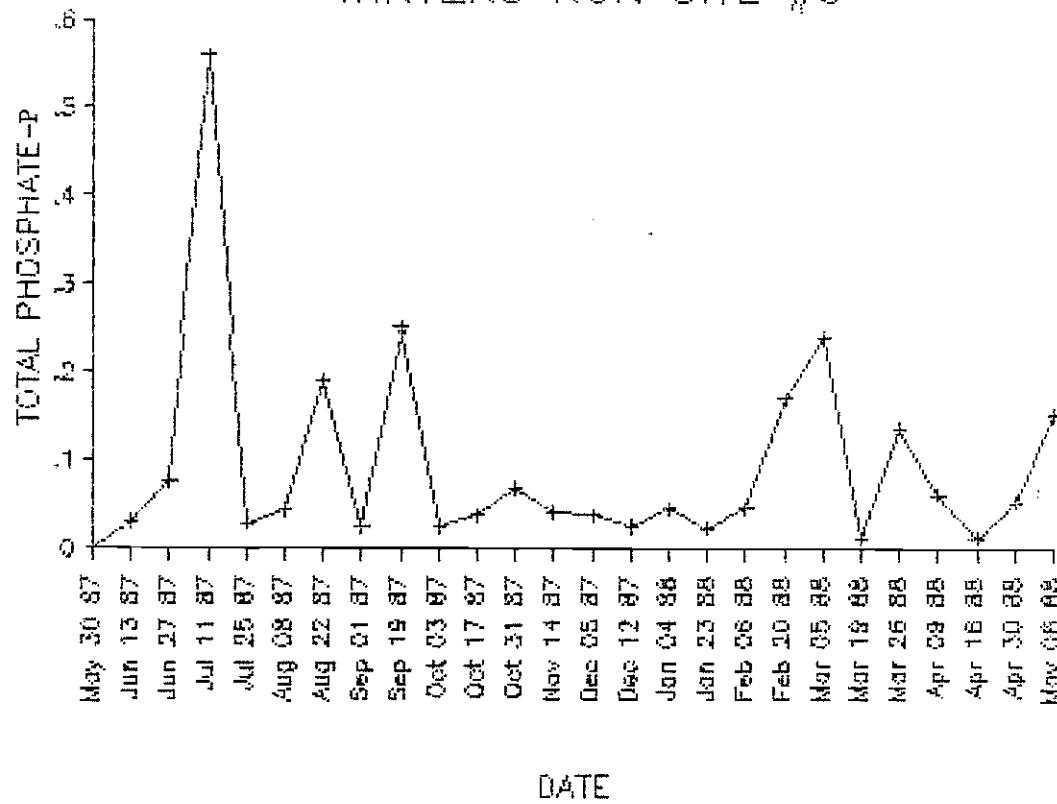
WINTERS RUN SITE #3



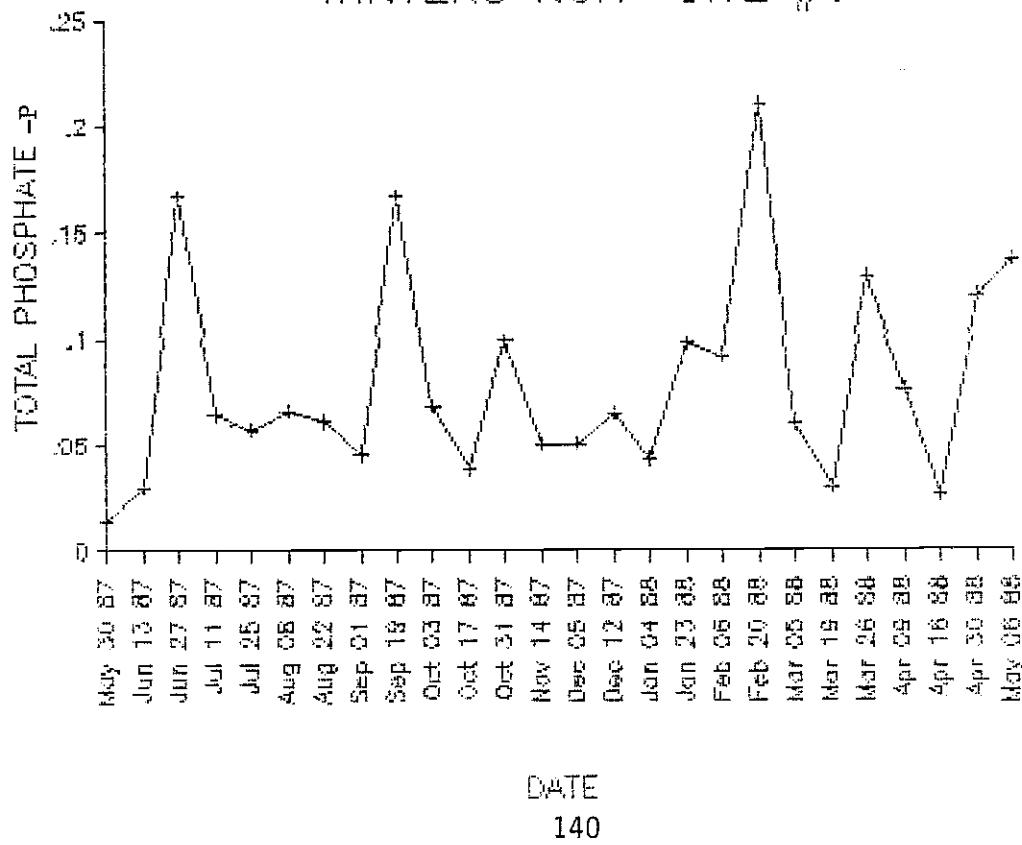
WINTERS RUN SITE #4



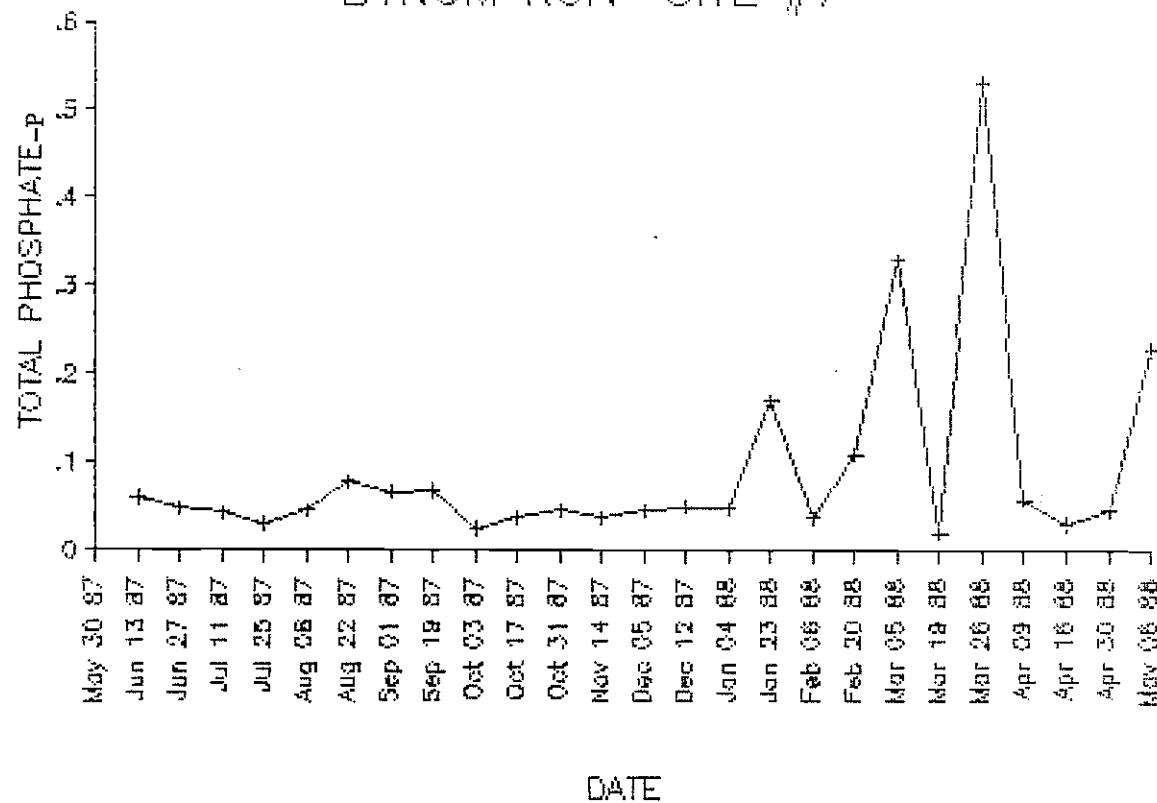
WINTERS RUN SITE #5



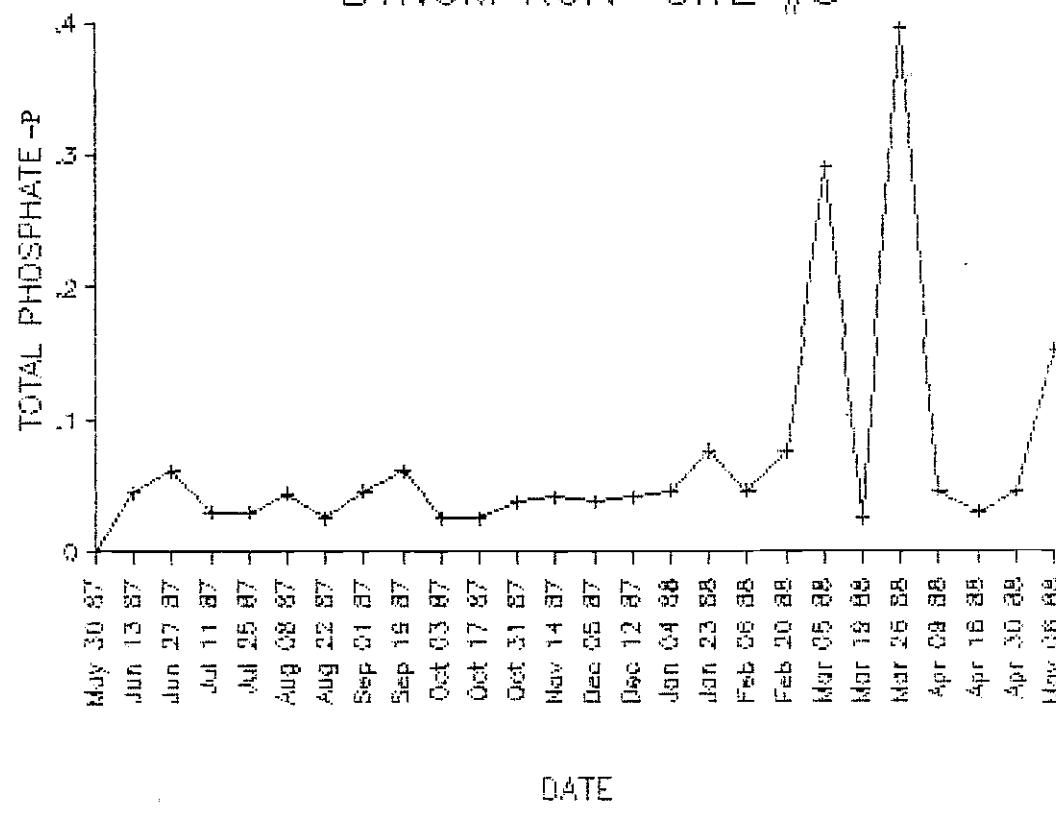
WINTERS RUN SITE #6



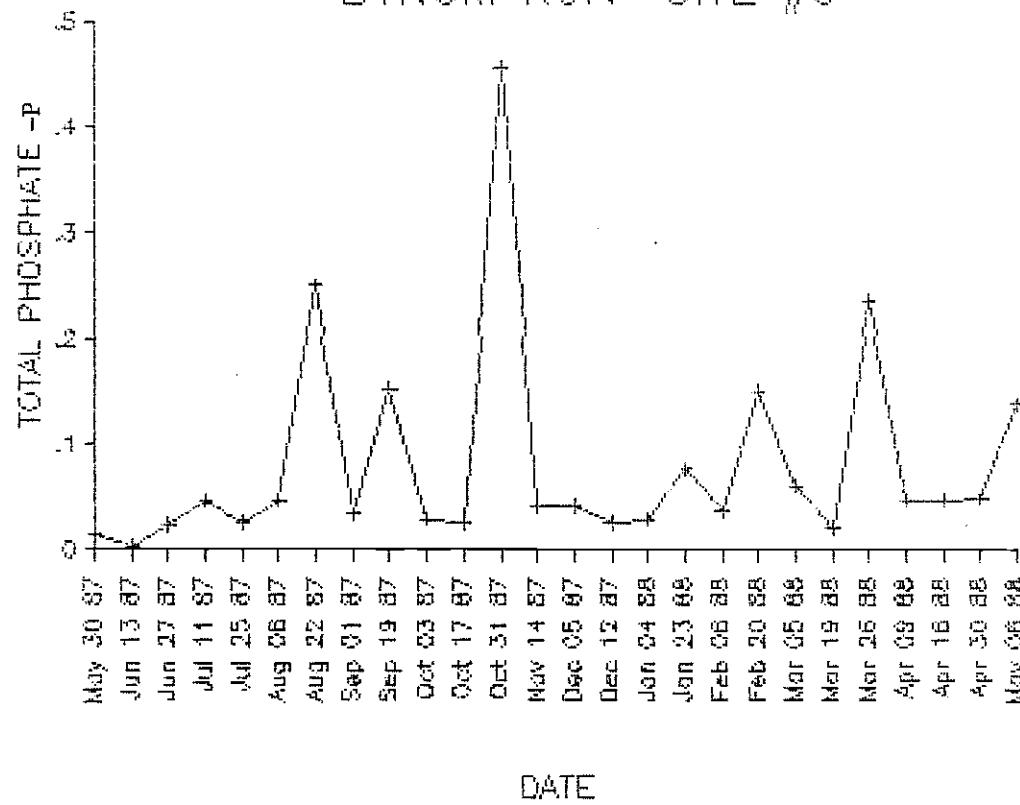
BYNUM RUN SITE #7



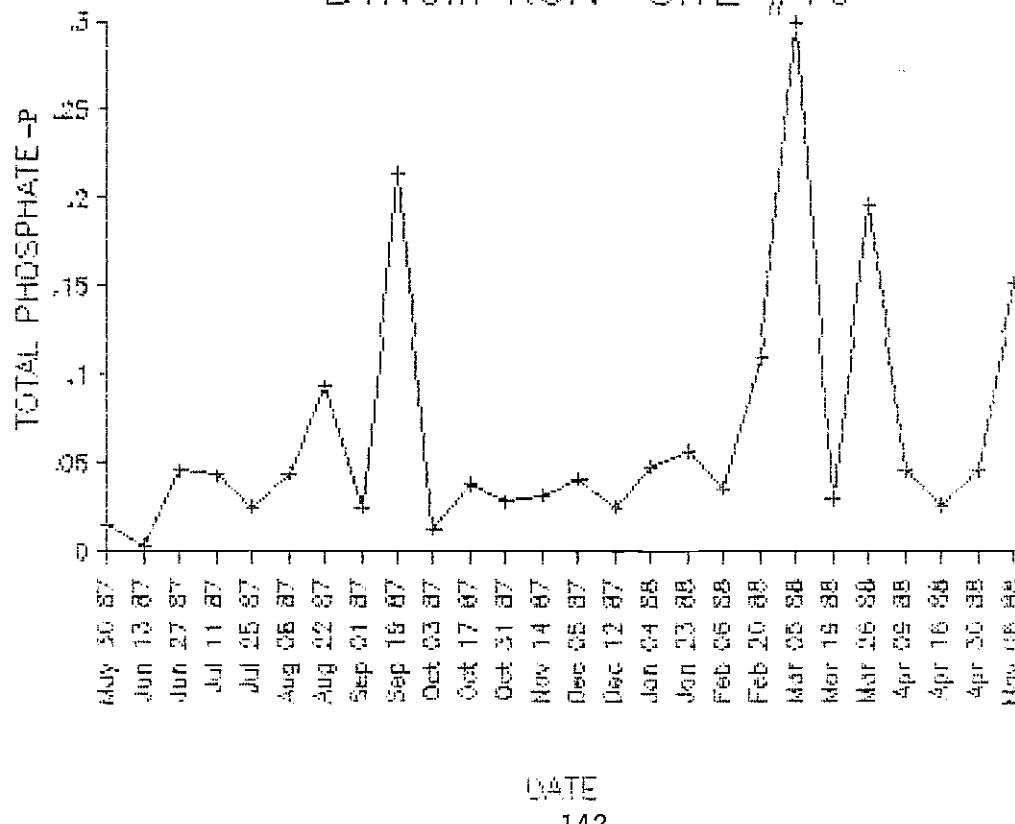
BYNUM RUN SITE #8



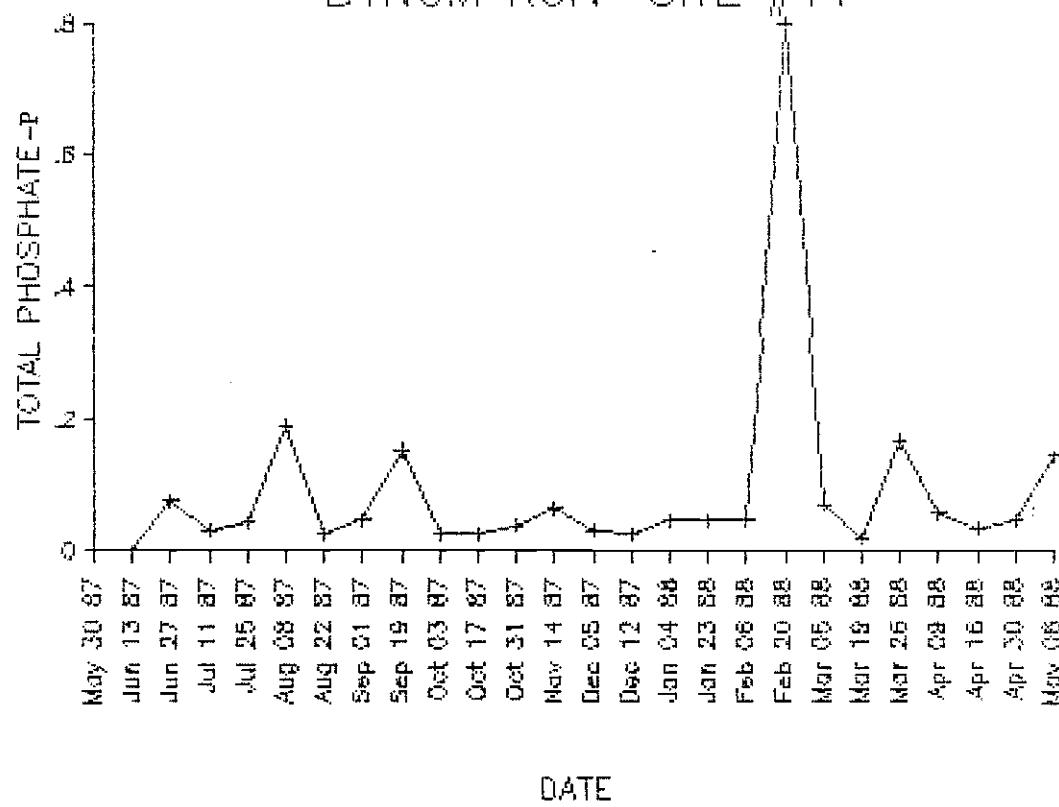
BYNUM RUN SITE #9



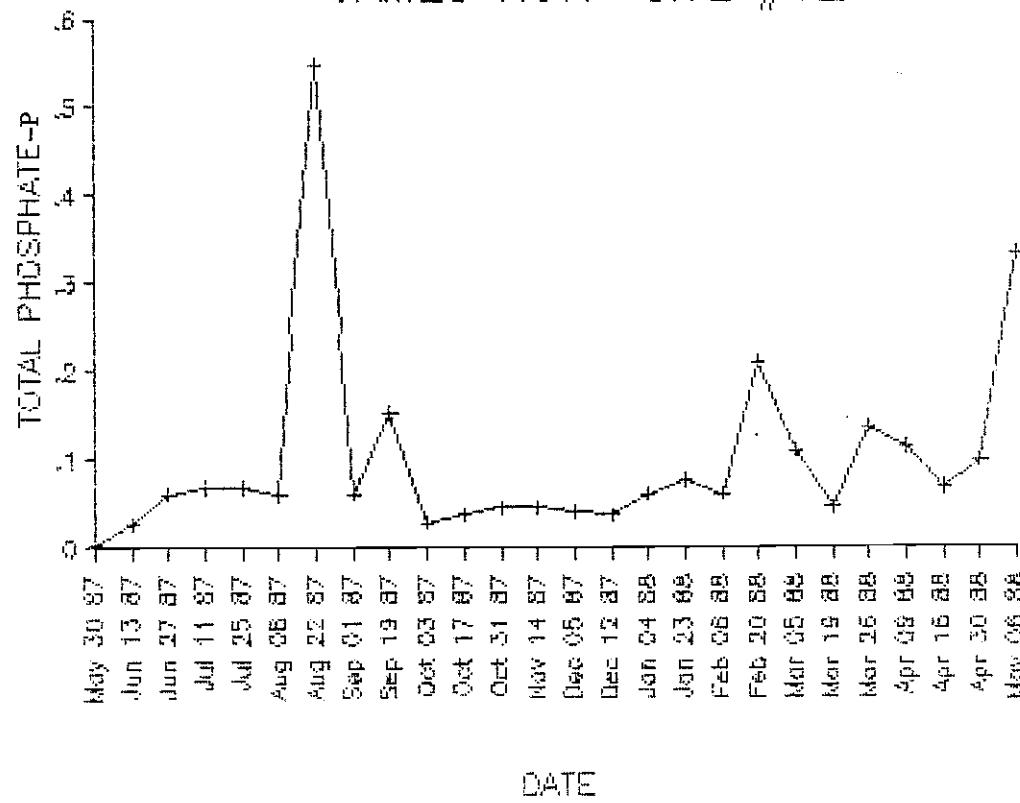
BYNUM RUN SITE #10



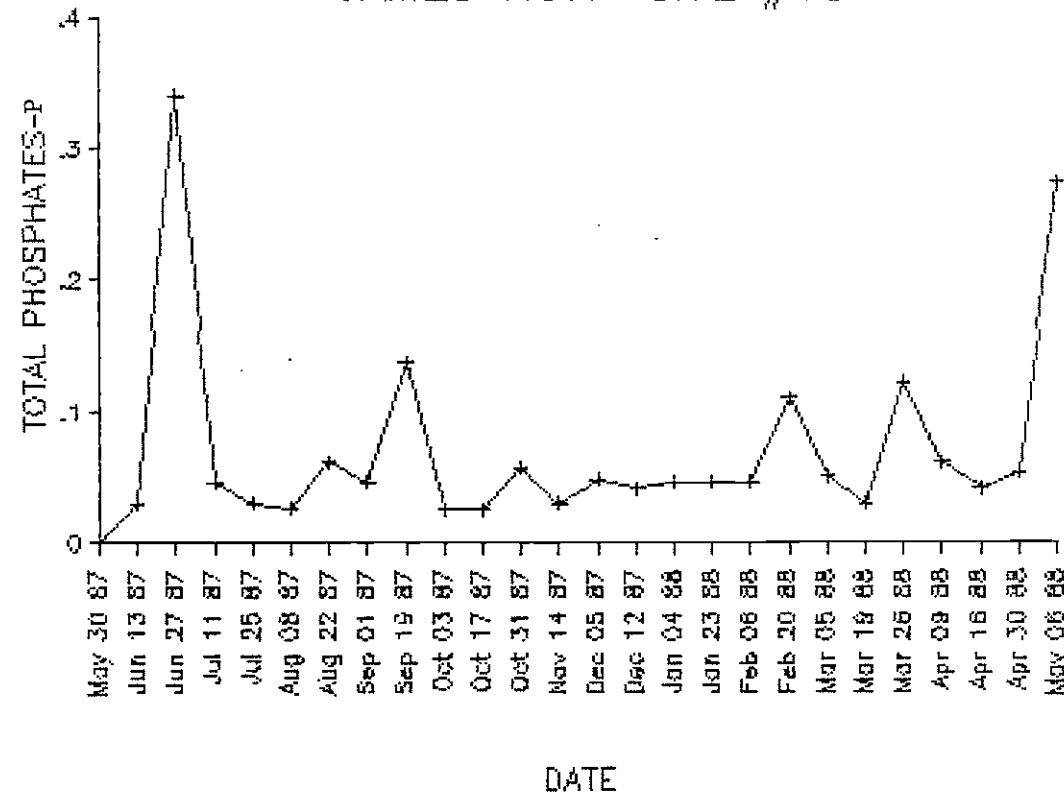
BYNUM RUN SITE #11



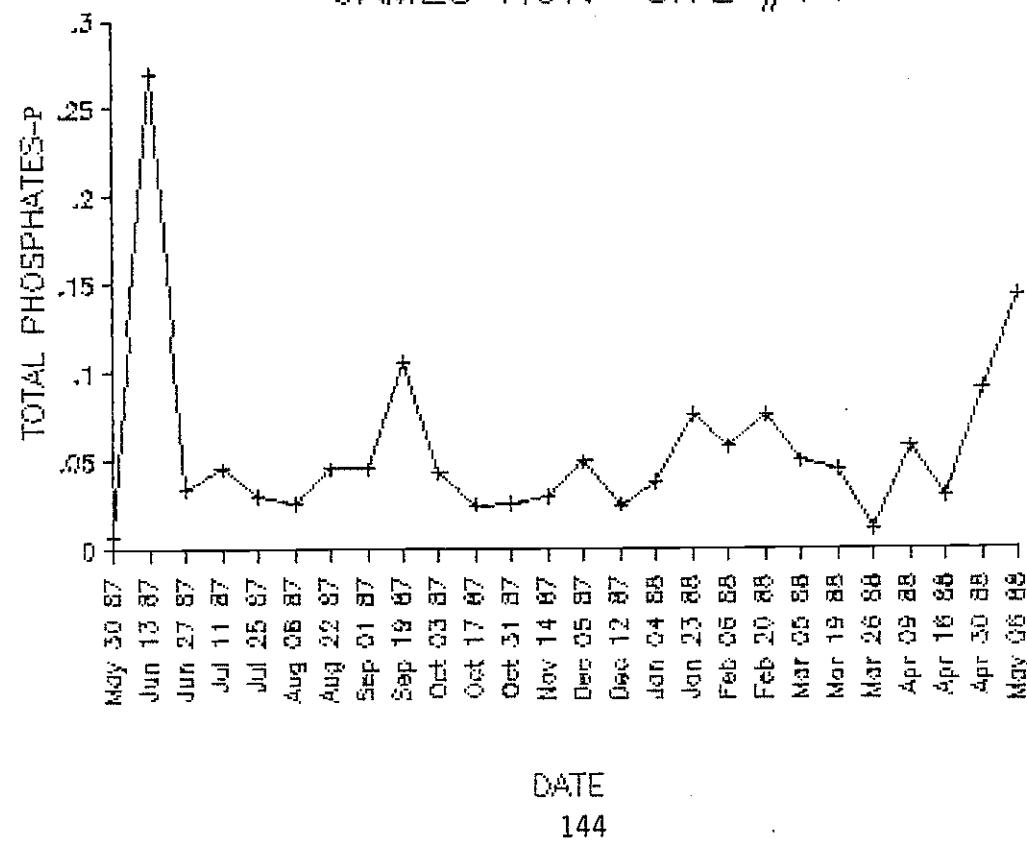
JAMES RUN SITE #12



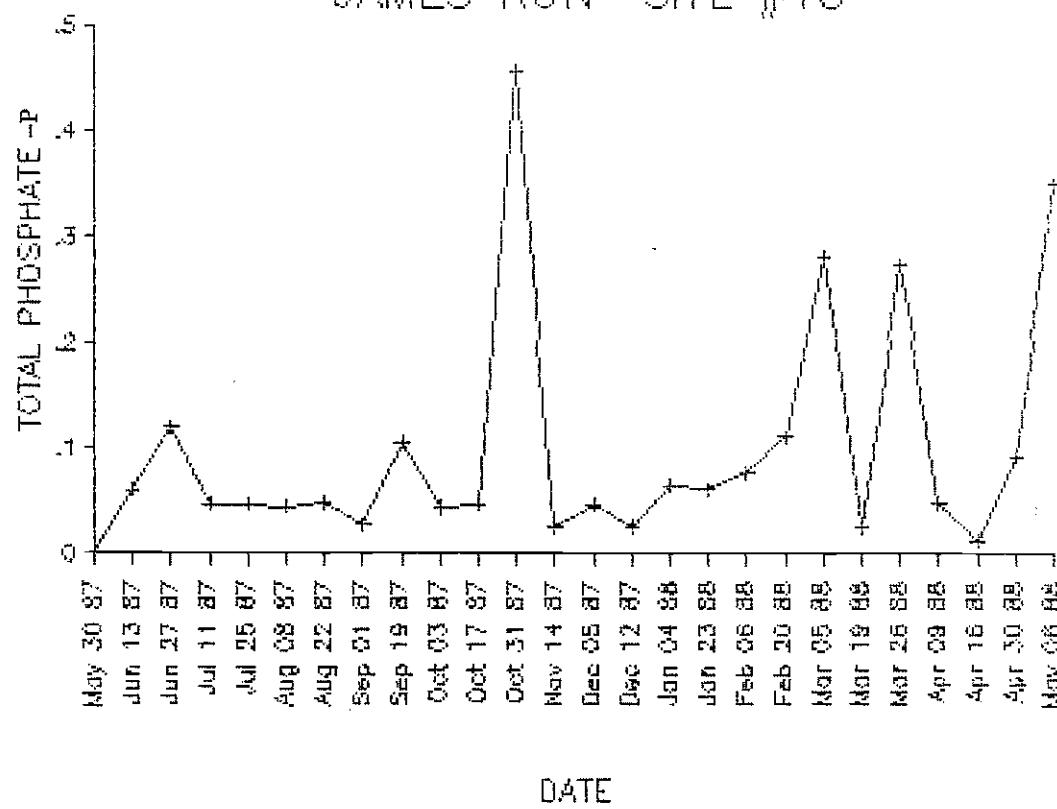
JAMES RUN SITE #13



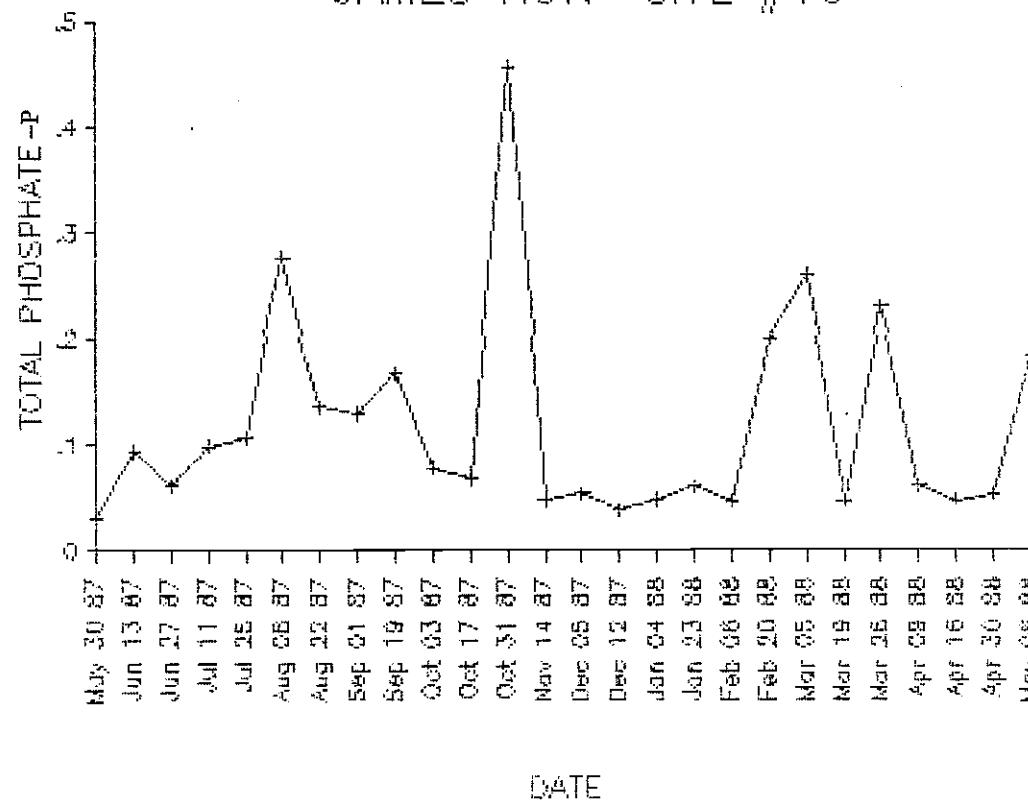
JAMES RUN SITE #14



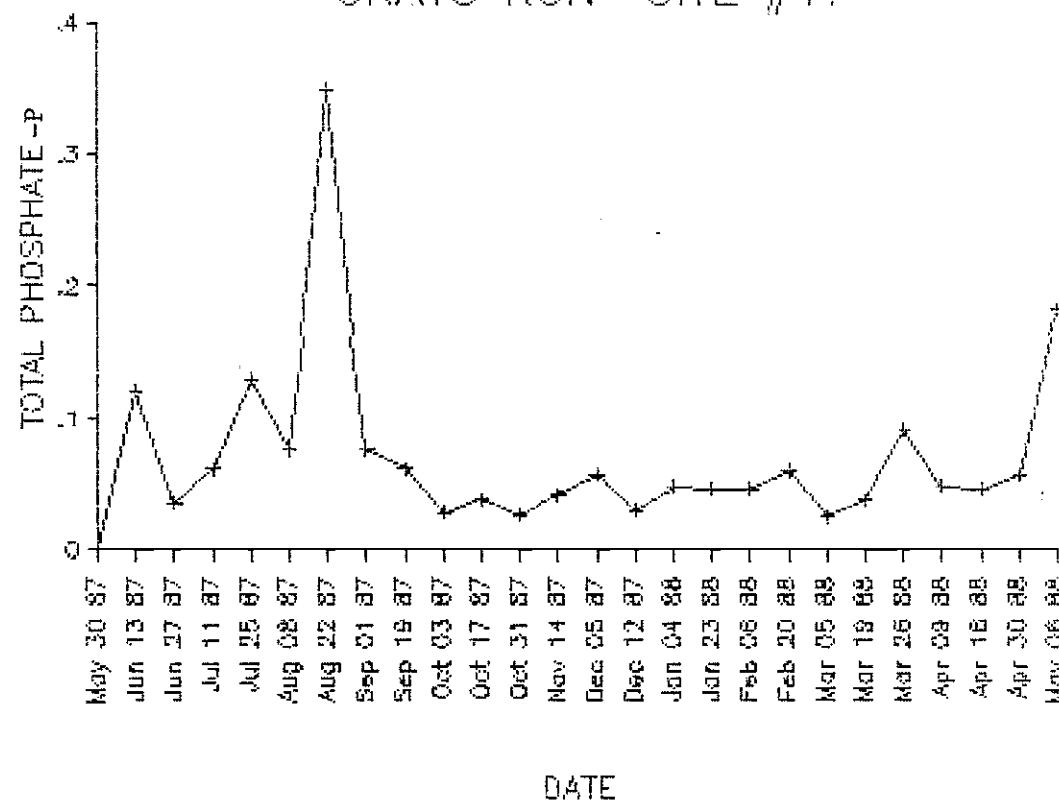
JAMES RUN SITE #15



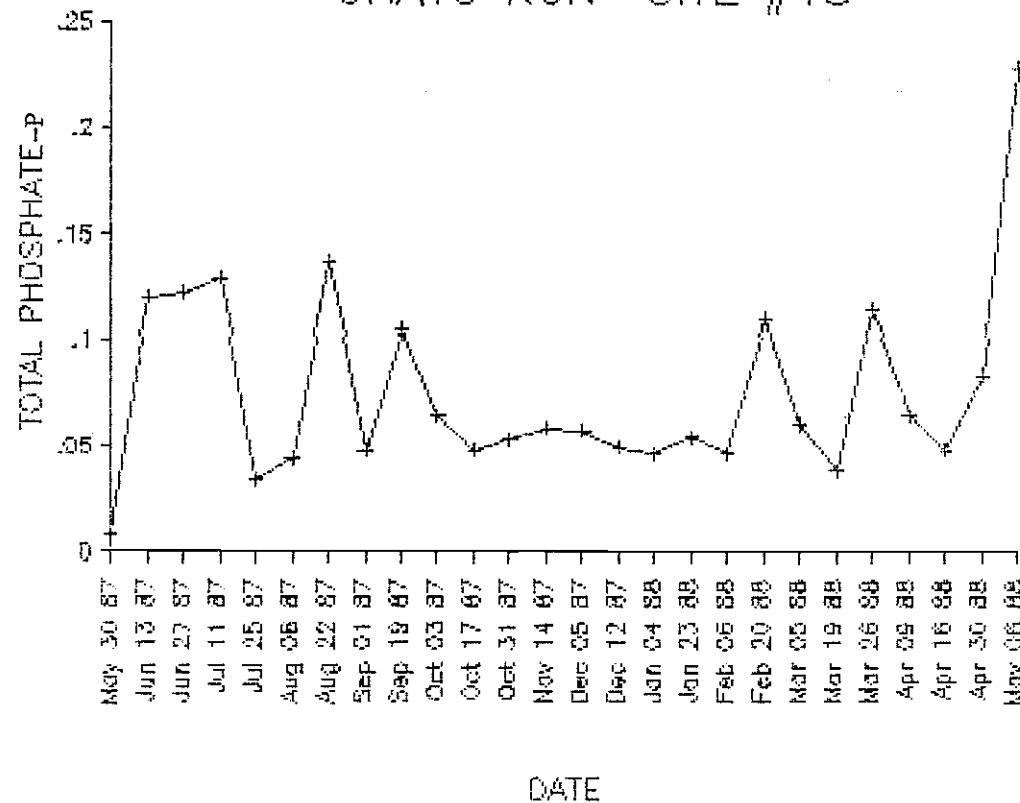
JAMES RUN SITE #16



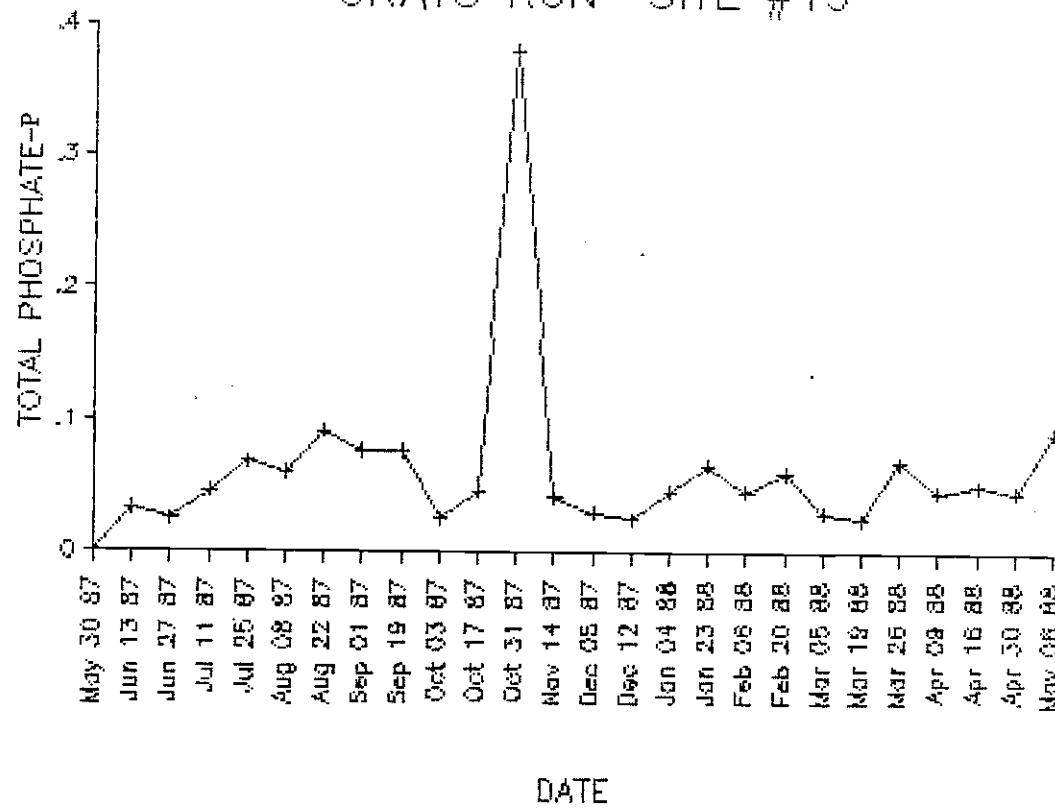
GRAYS RUN SITE #17



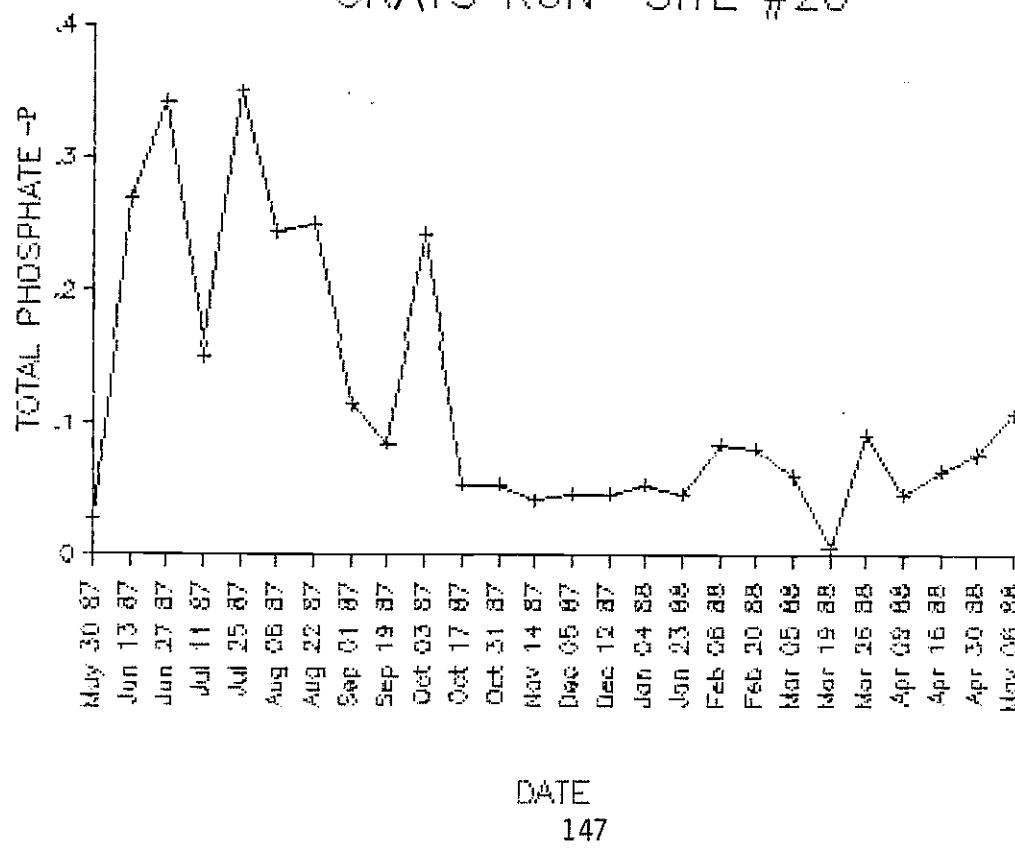
GRAYS RUN SITE #18



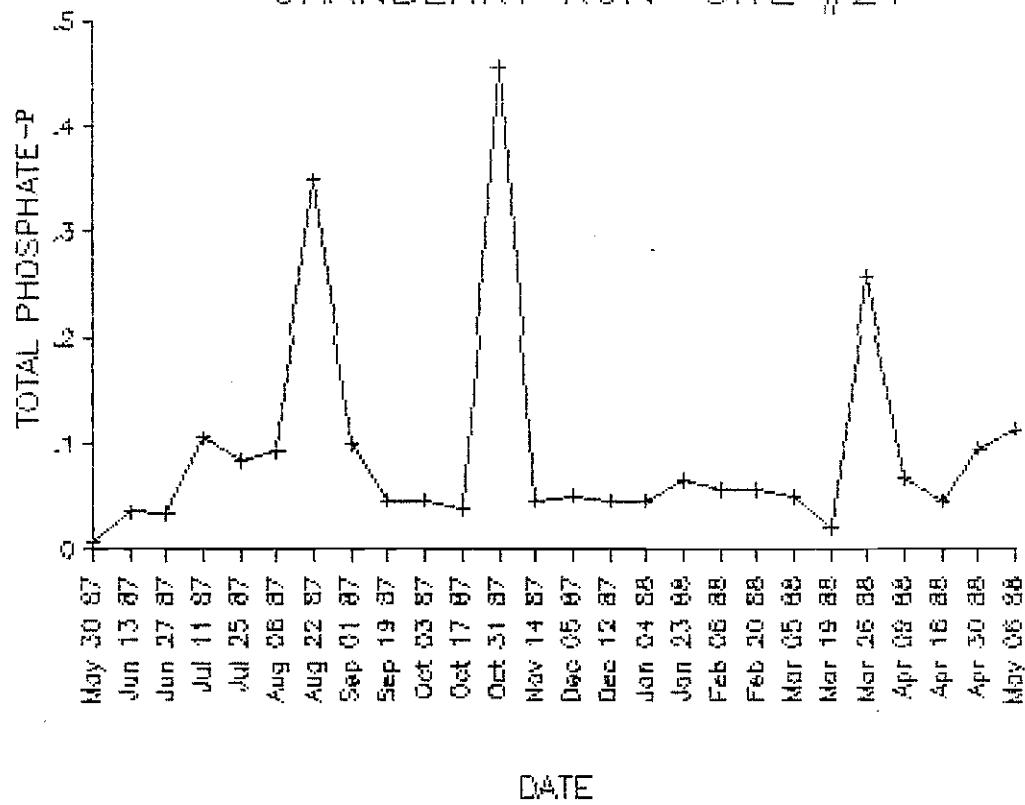
GRAYS RUN SITE #19



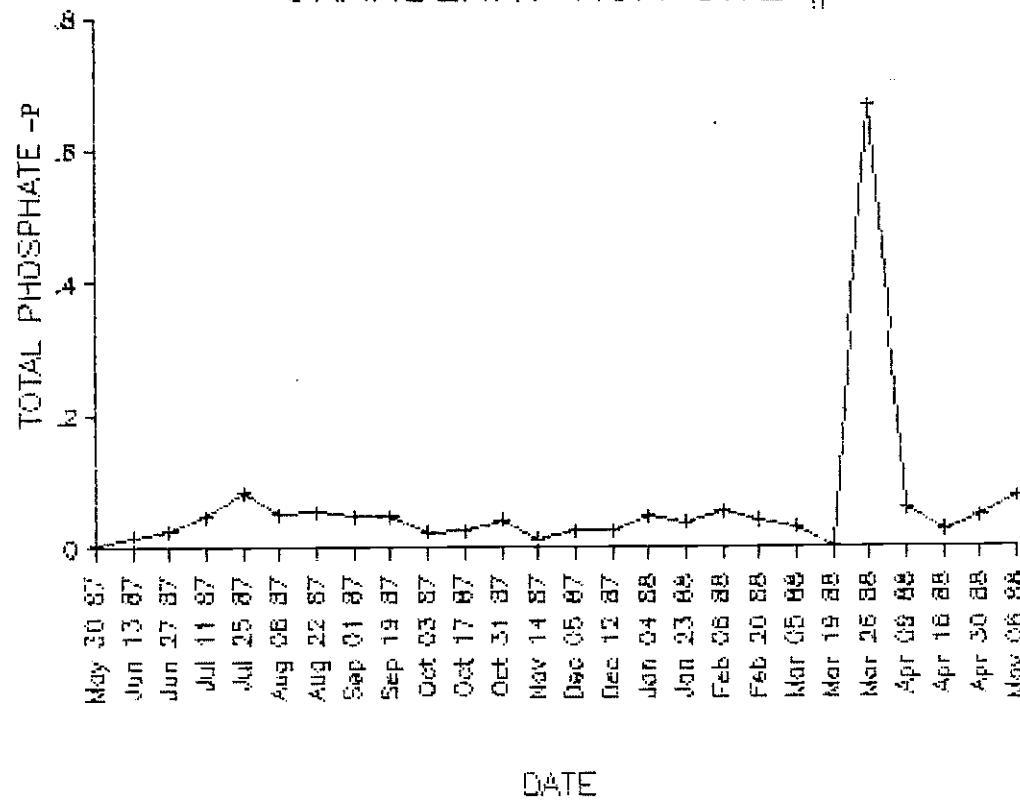
GRAYS RUN SITE #20



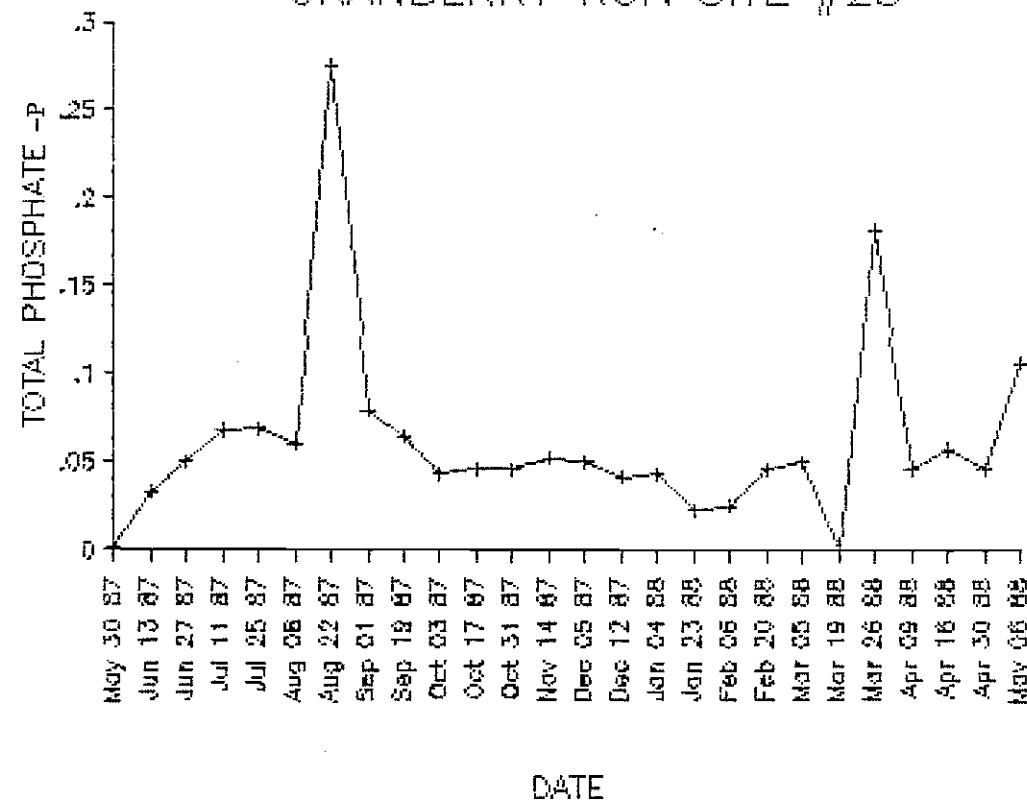
CRANBERRY RUN SITE #21



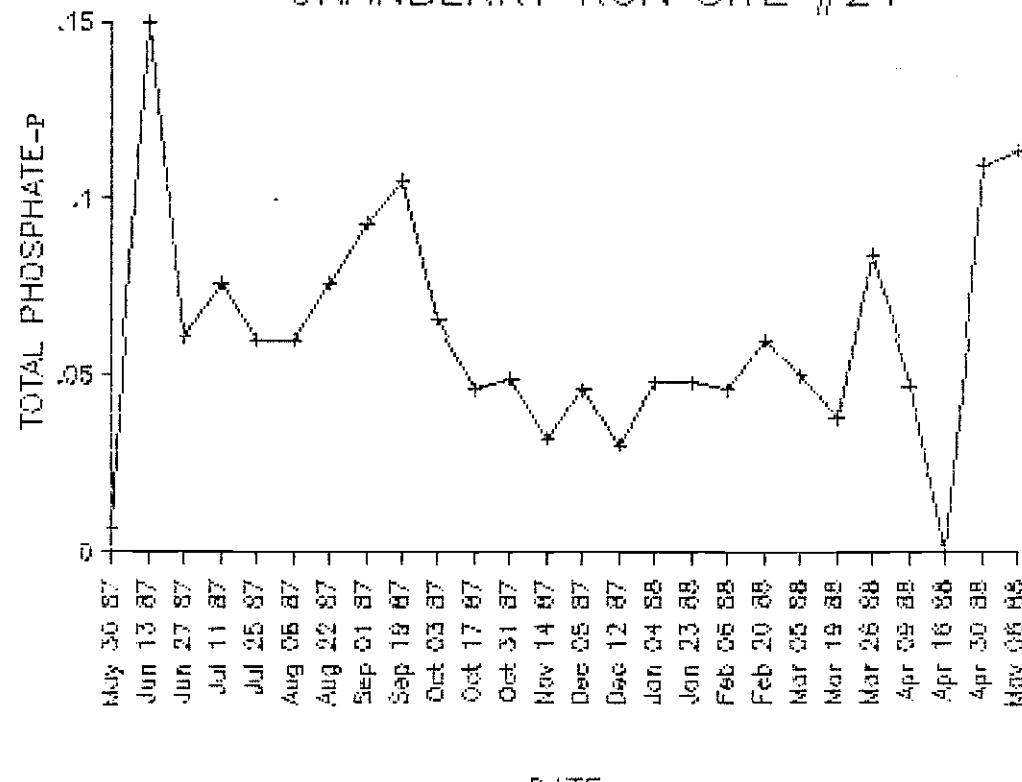
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23

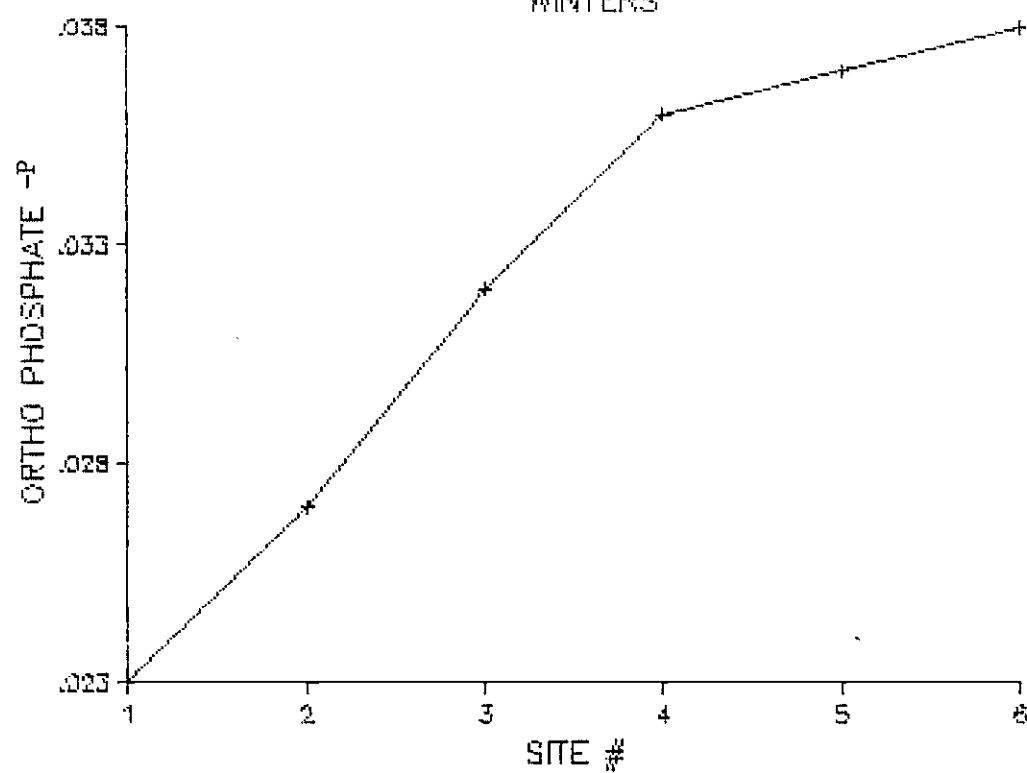


CRANBERRY RUN SITE #24

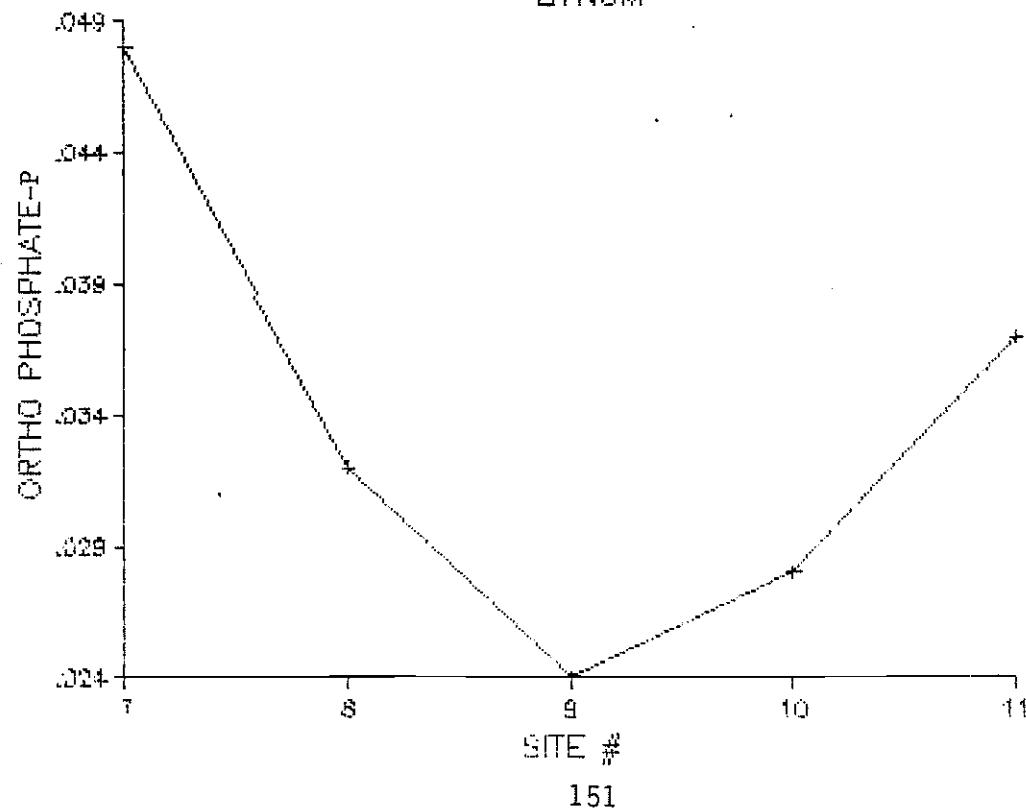


Ortho Phosphate-P
(mg/l)

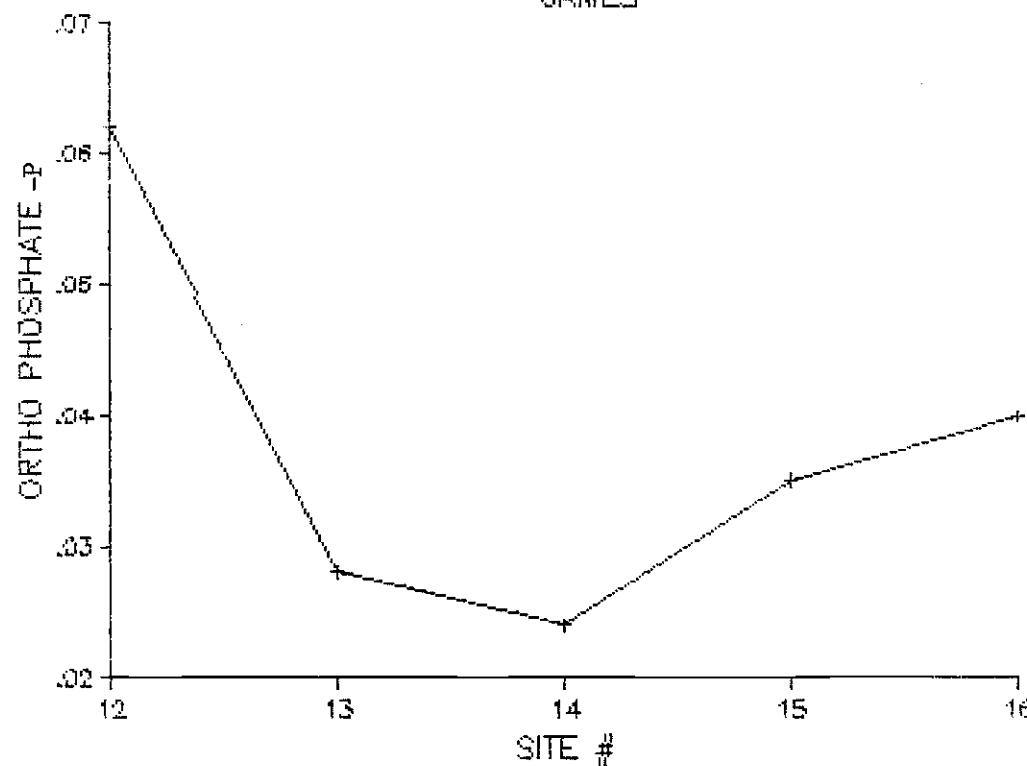
YEARLY AVERAGES
WINTERS



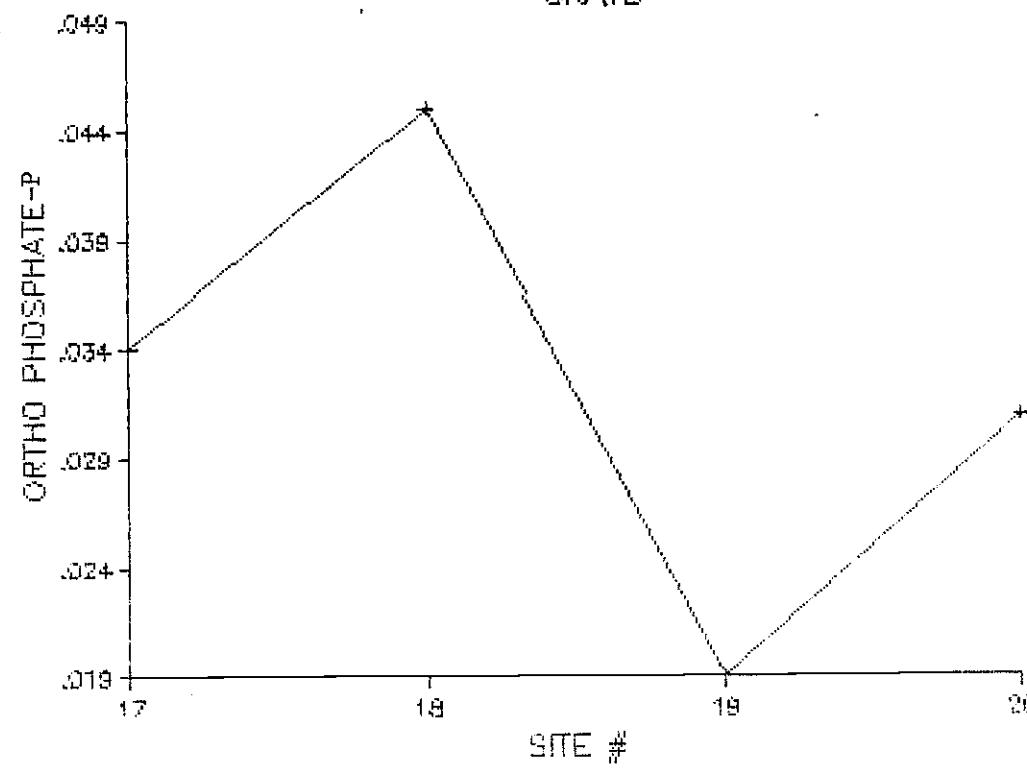
YEARLY AVERAGES
BYNUM



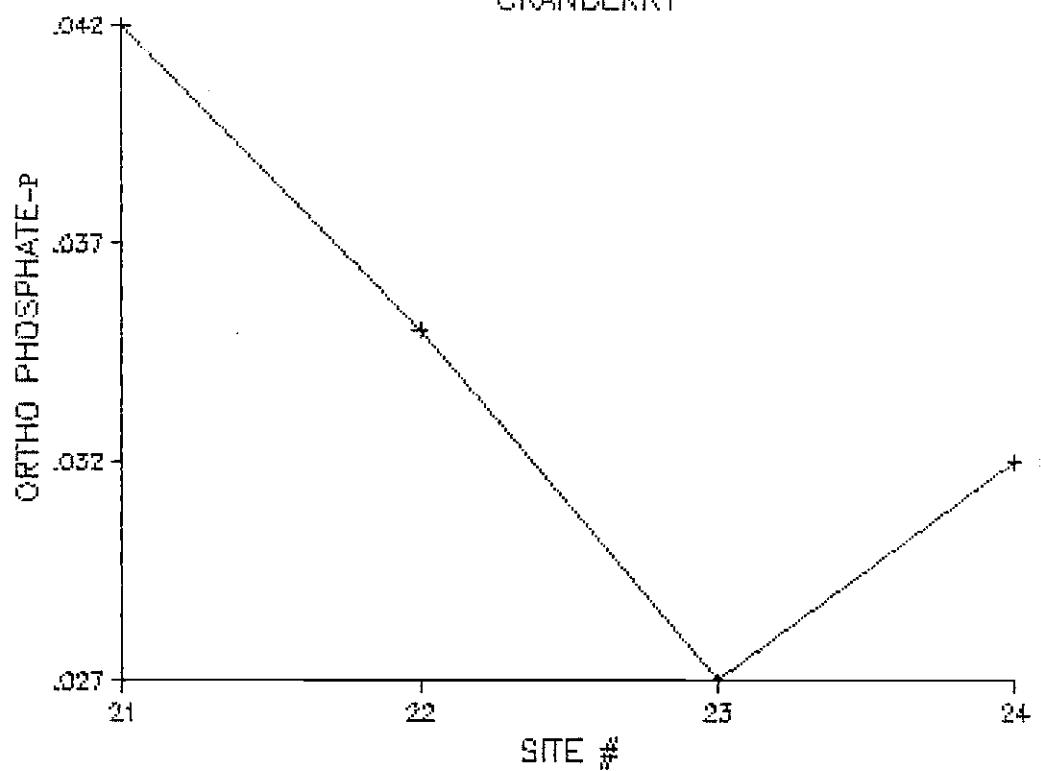
YEARLY AVERAGES
JAMES



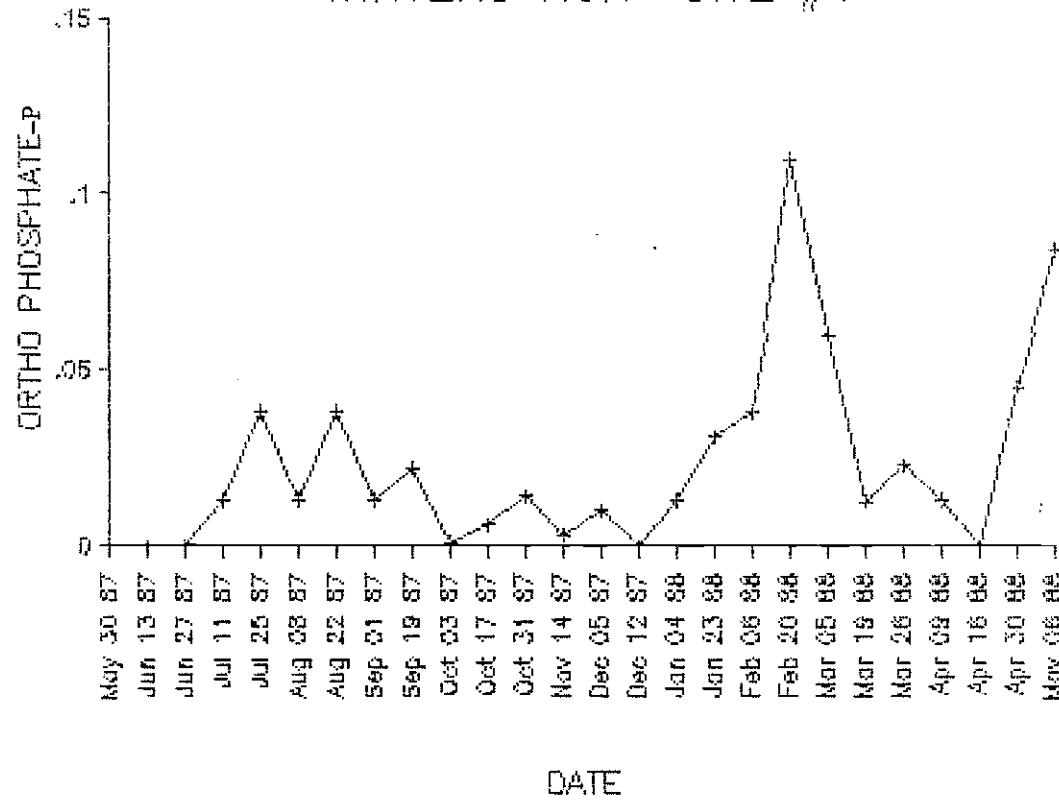
YEARLY AVERAGES
GRAYS



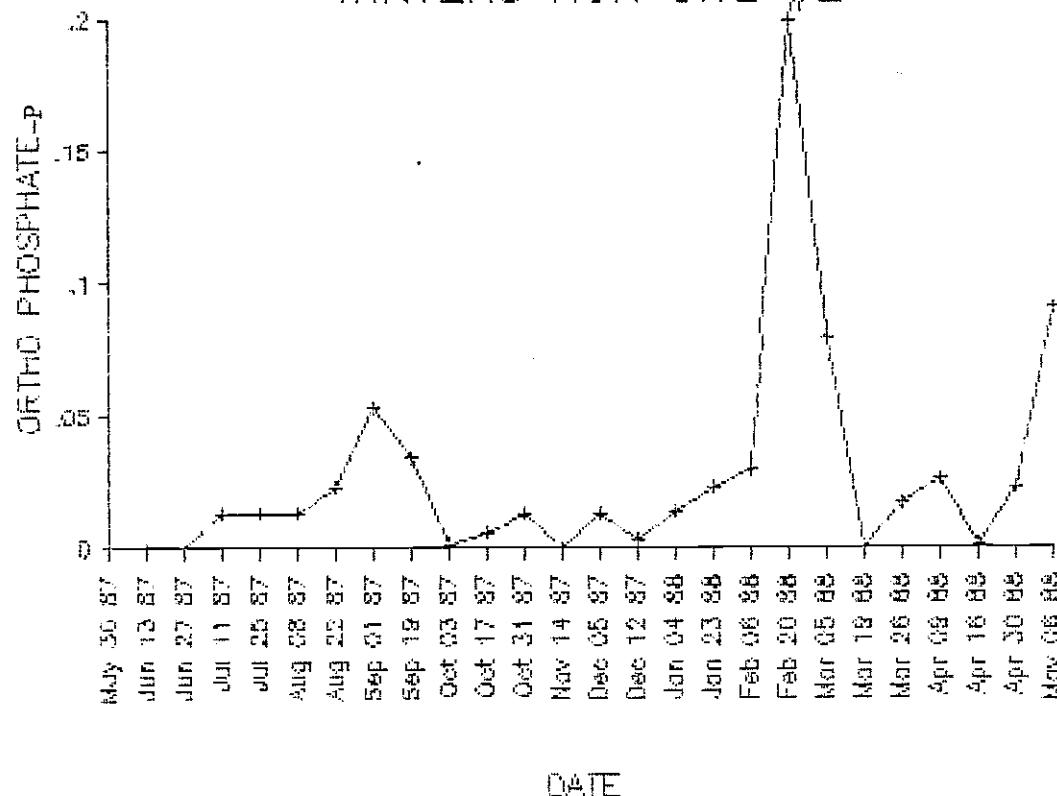
YEARLY AVERAGES
CRANBERRY



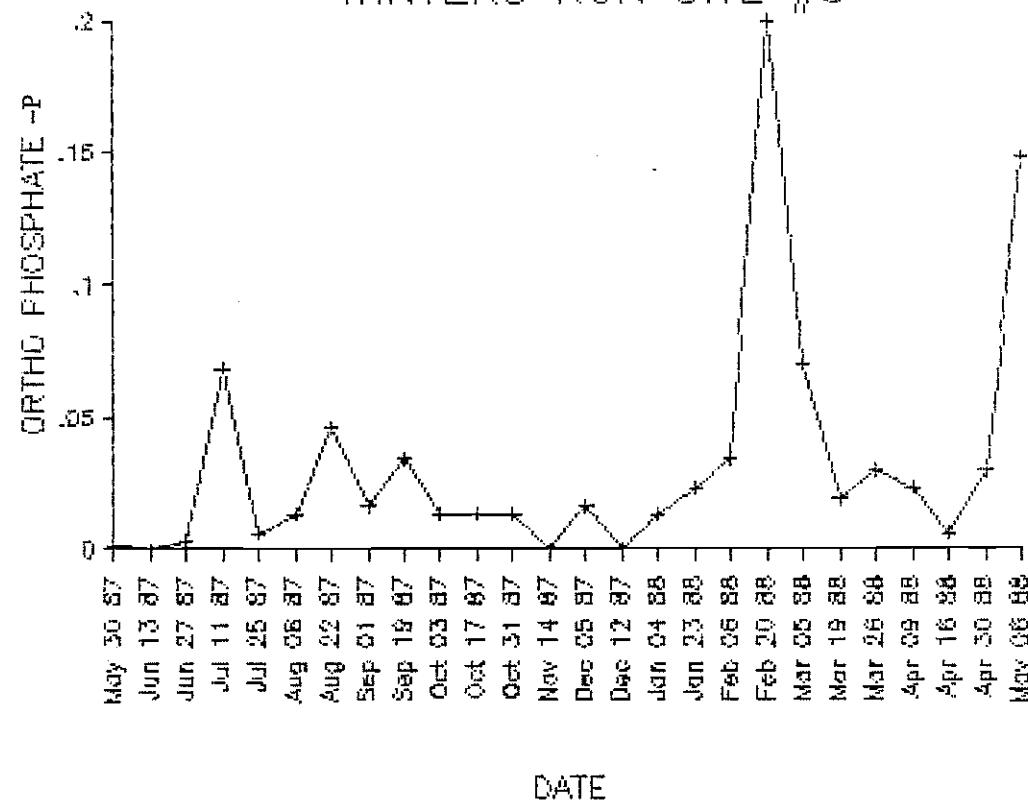
WINTERS RUN SITE #1



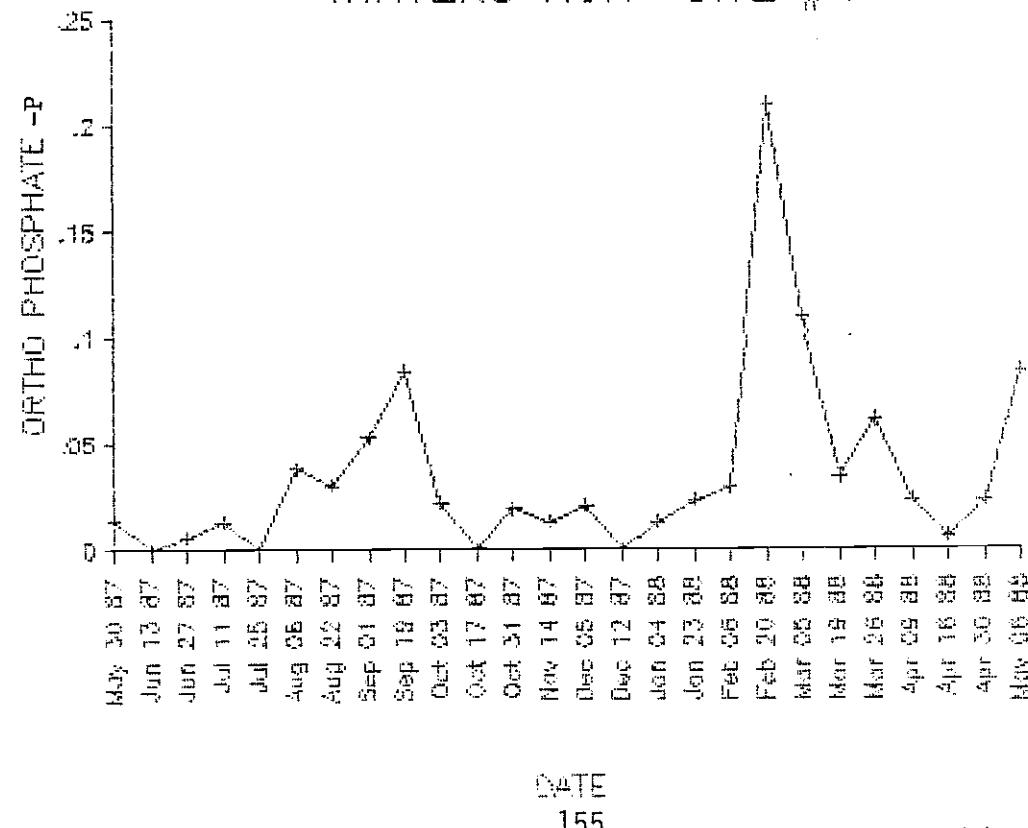
WINTERS RUN SITE #2



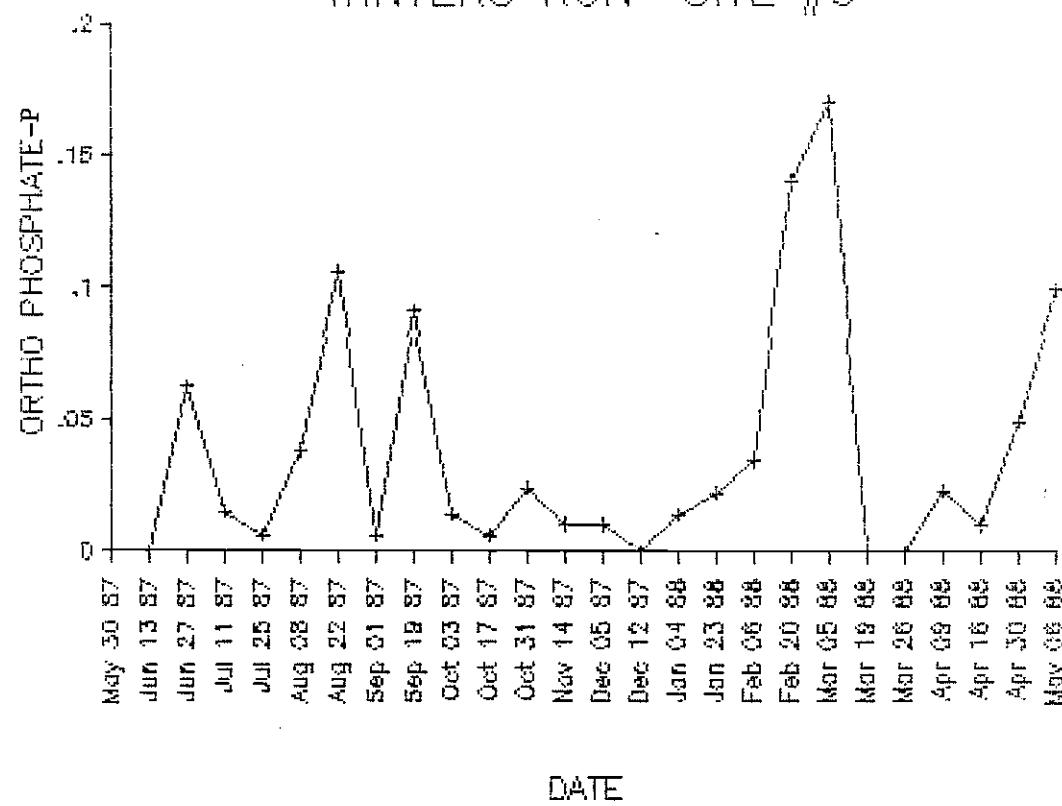
WINTERS RUN SITE #3



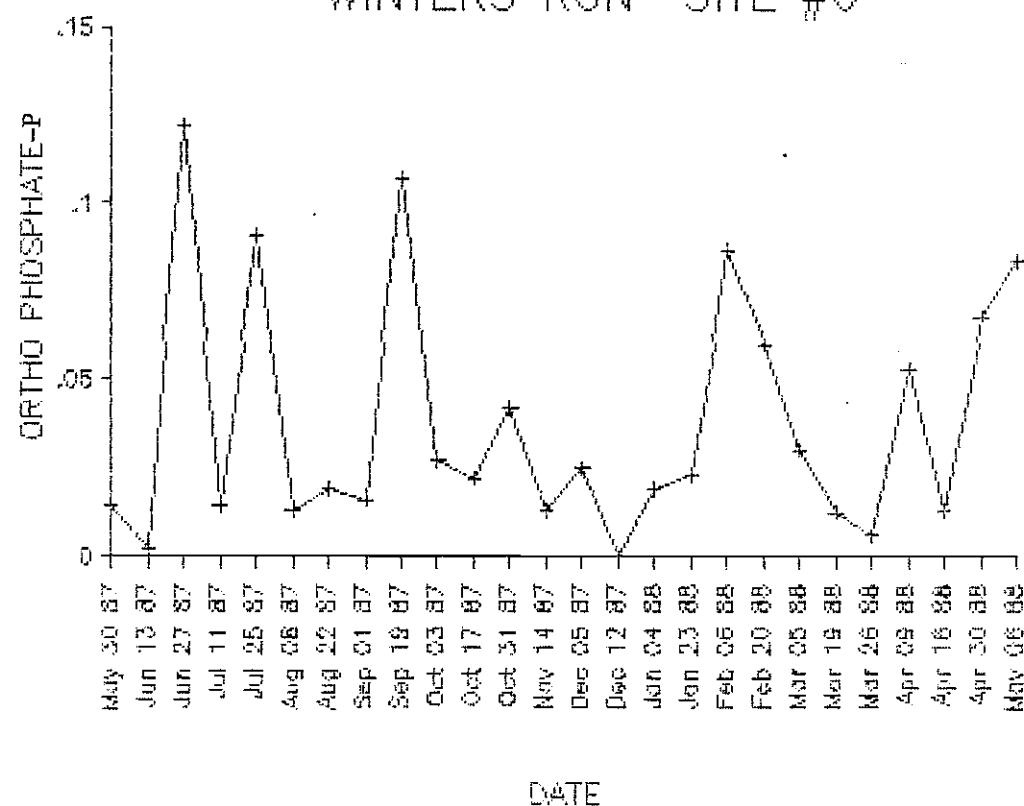
WINTERS RUN SITE #4



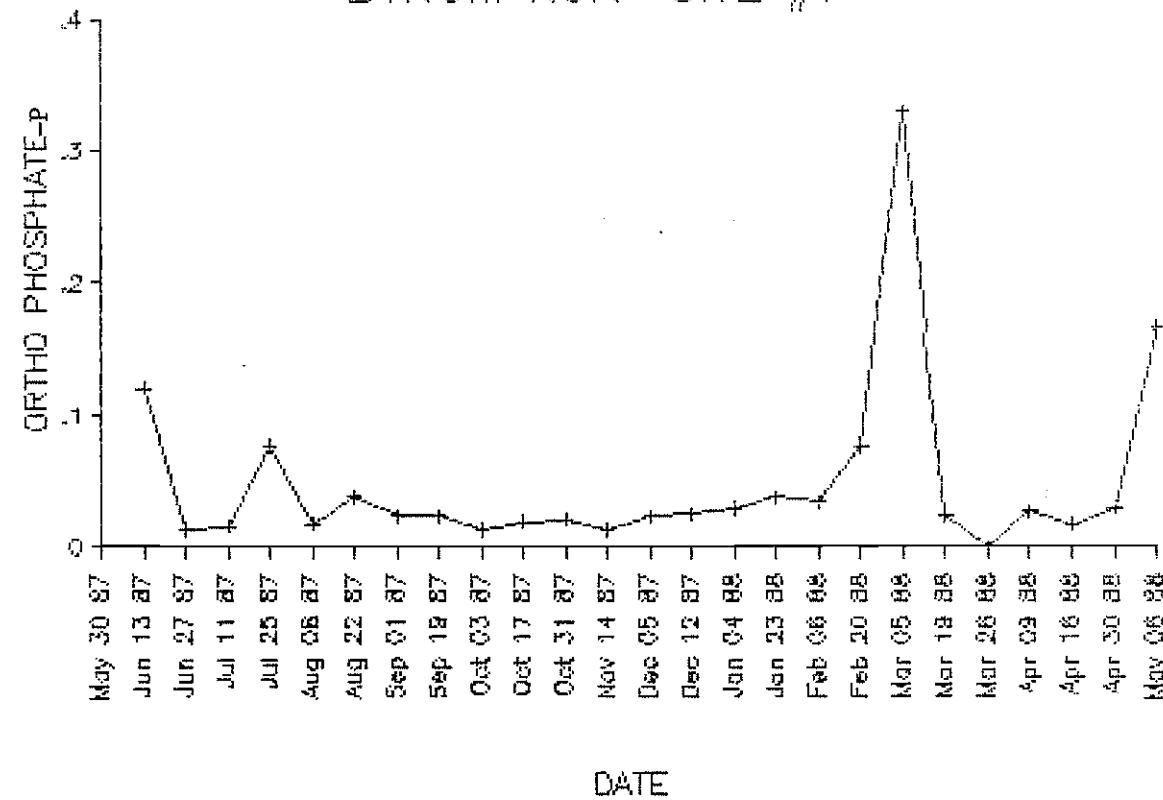
WINTERS RUN SITE #5



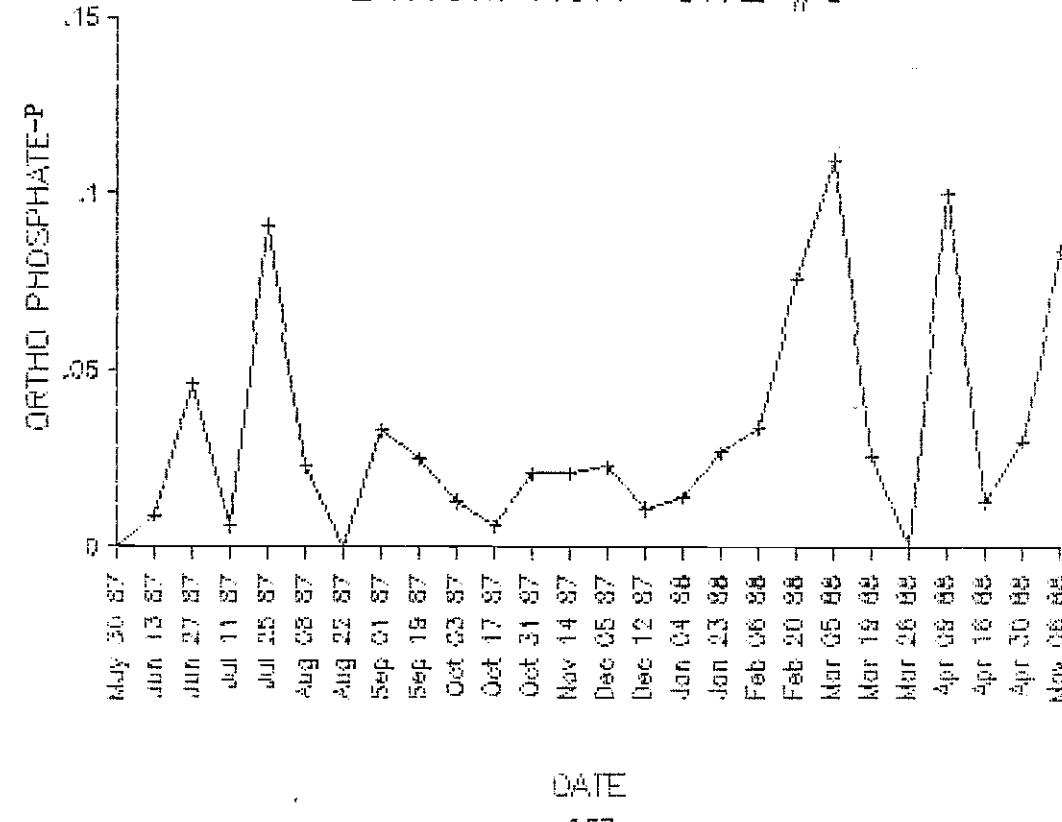
WINTERS RUN SITE #6



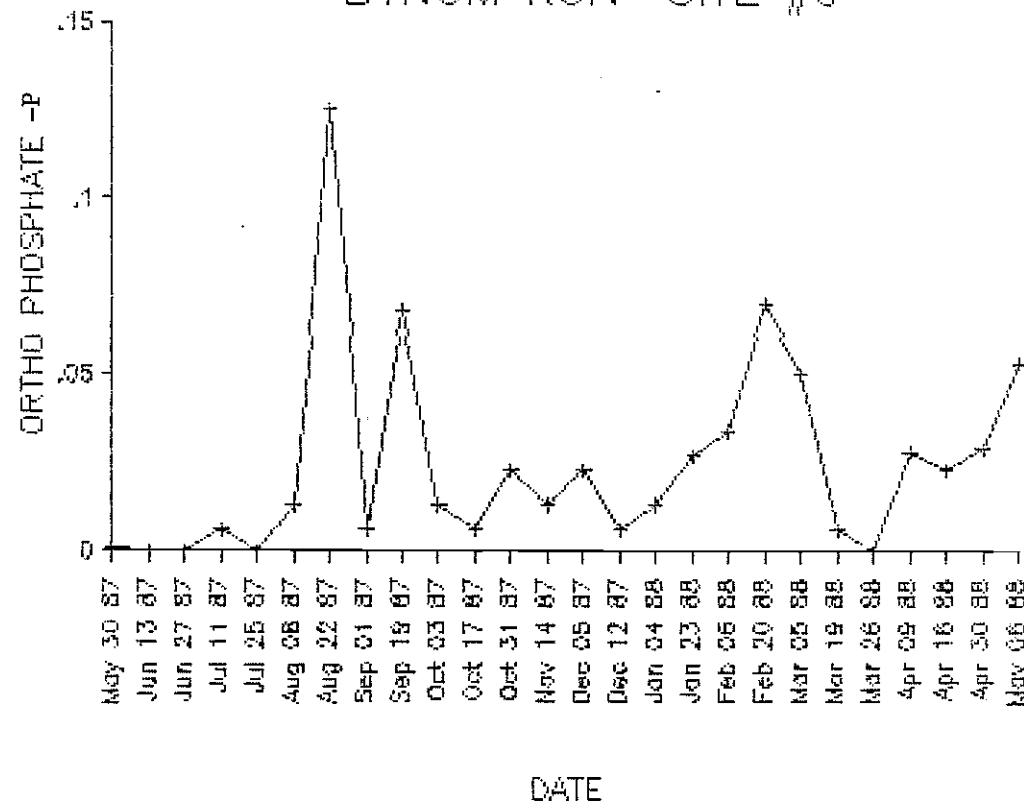
BYNUM RUN SITE #7



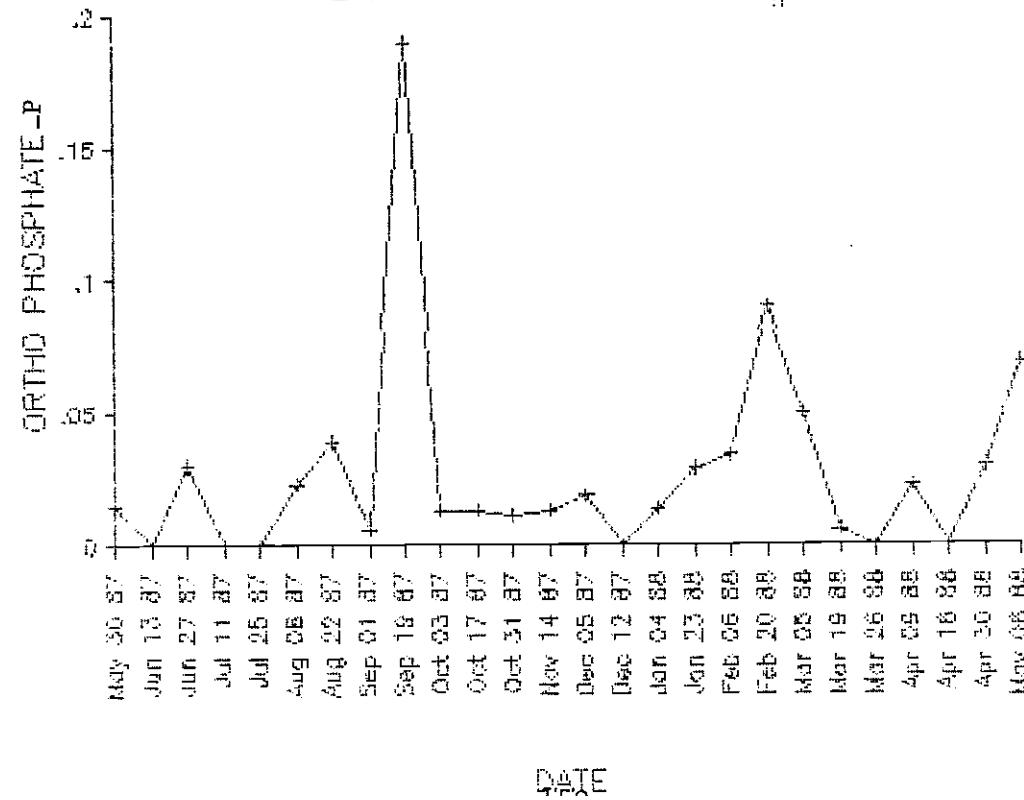
BYNUM RUN SITE #8



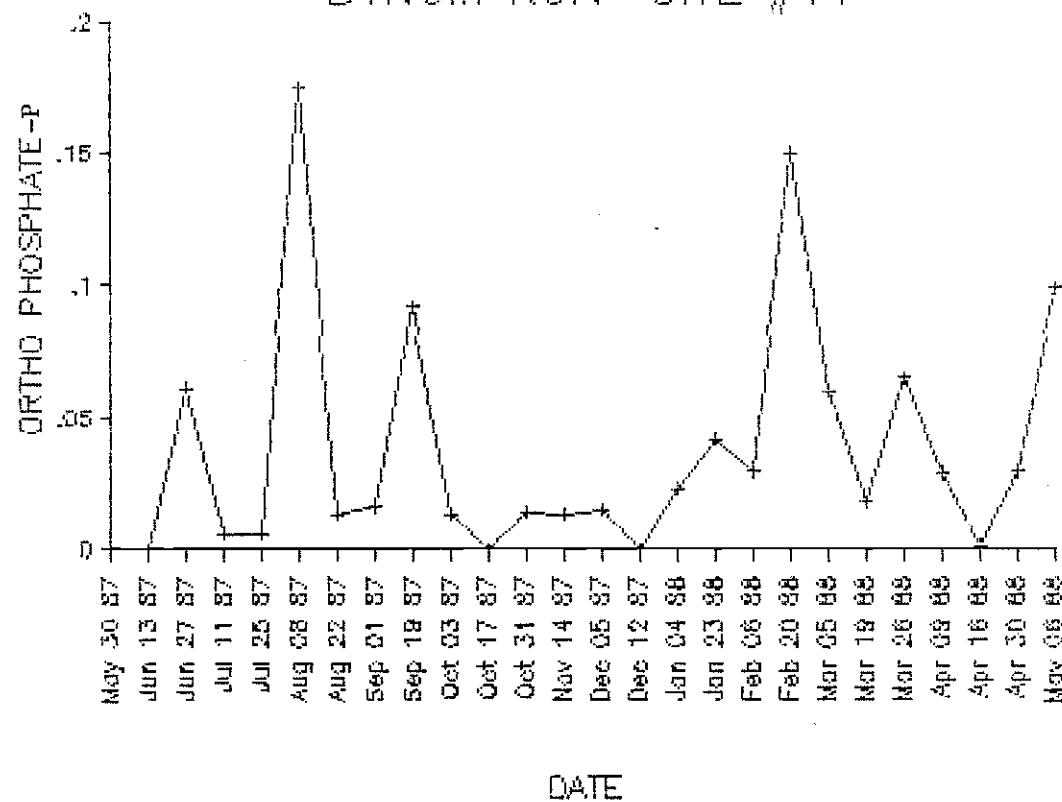
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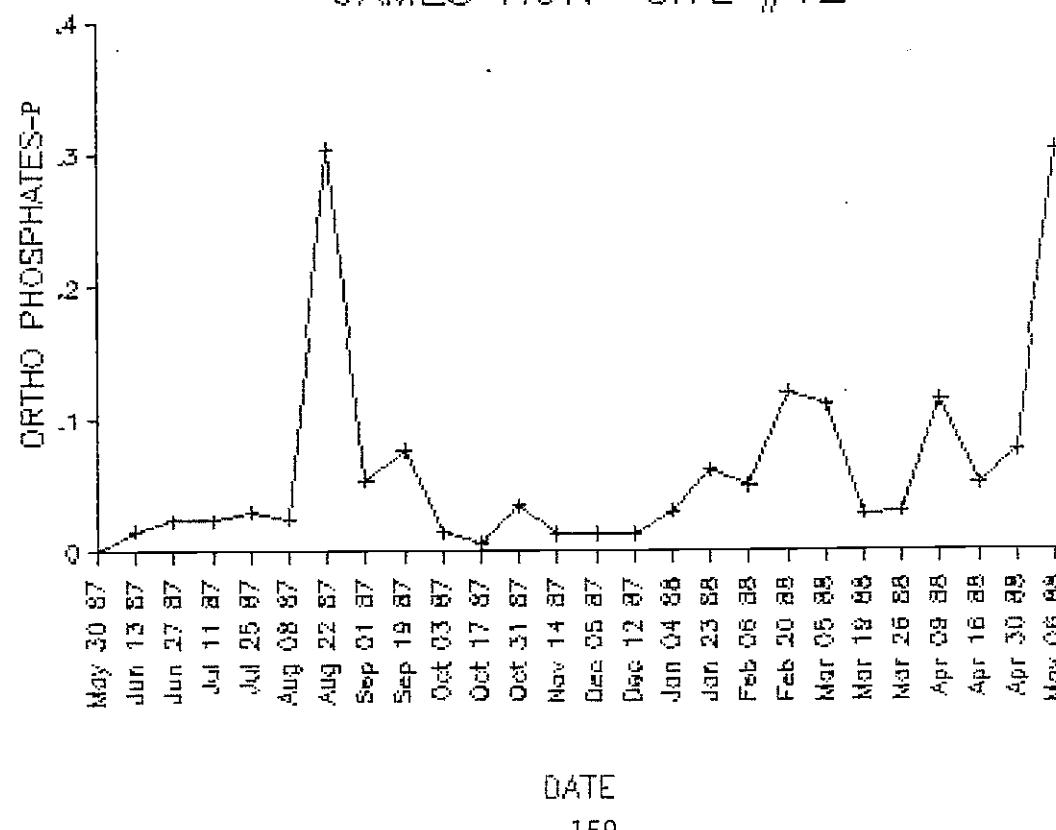
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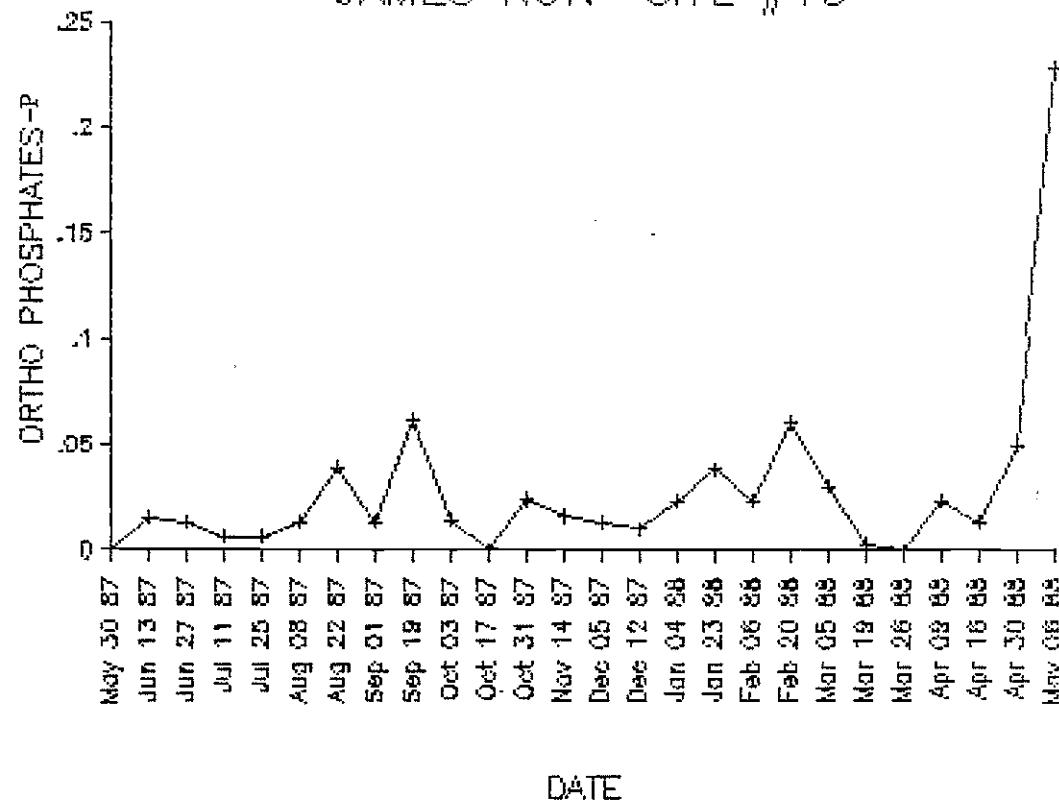
BYNUM RUN SITE #11



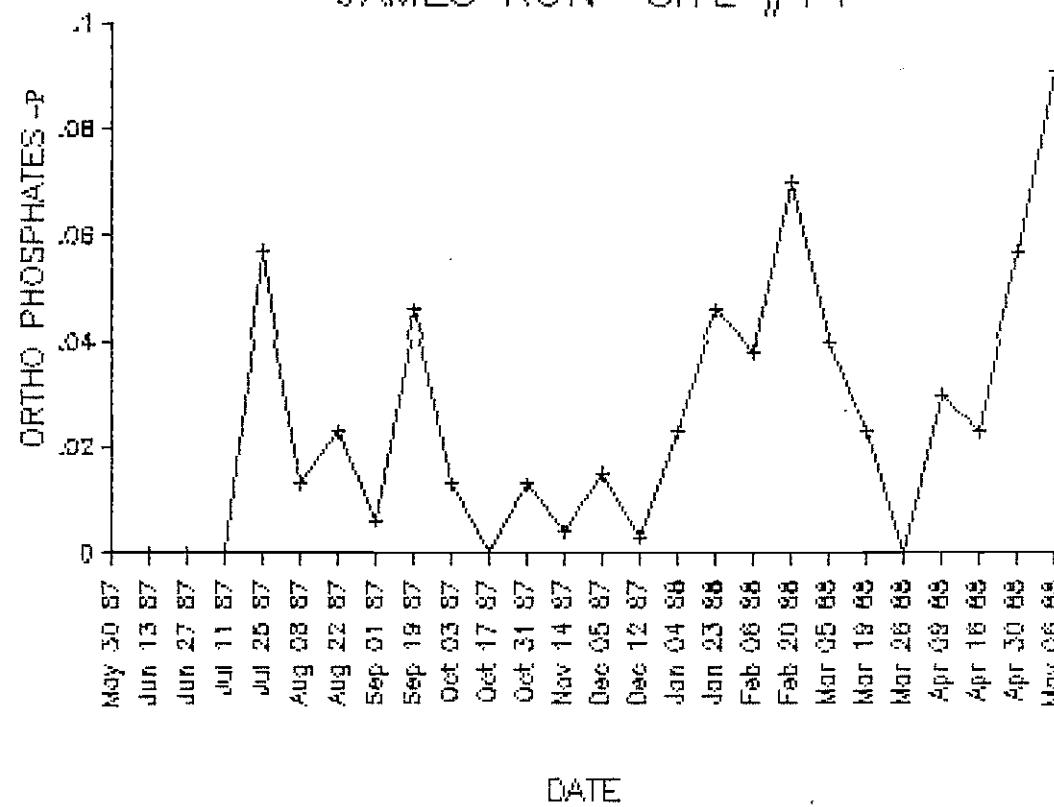
JAMES RUN SITE #12



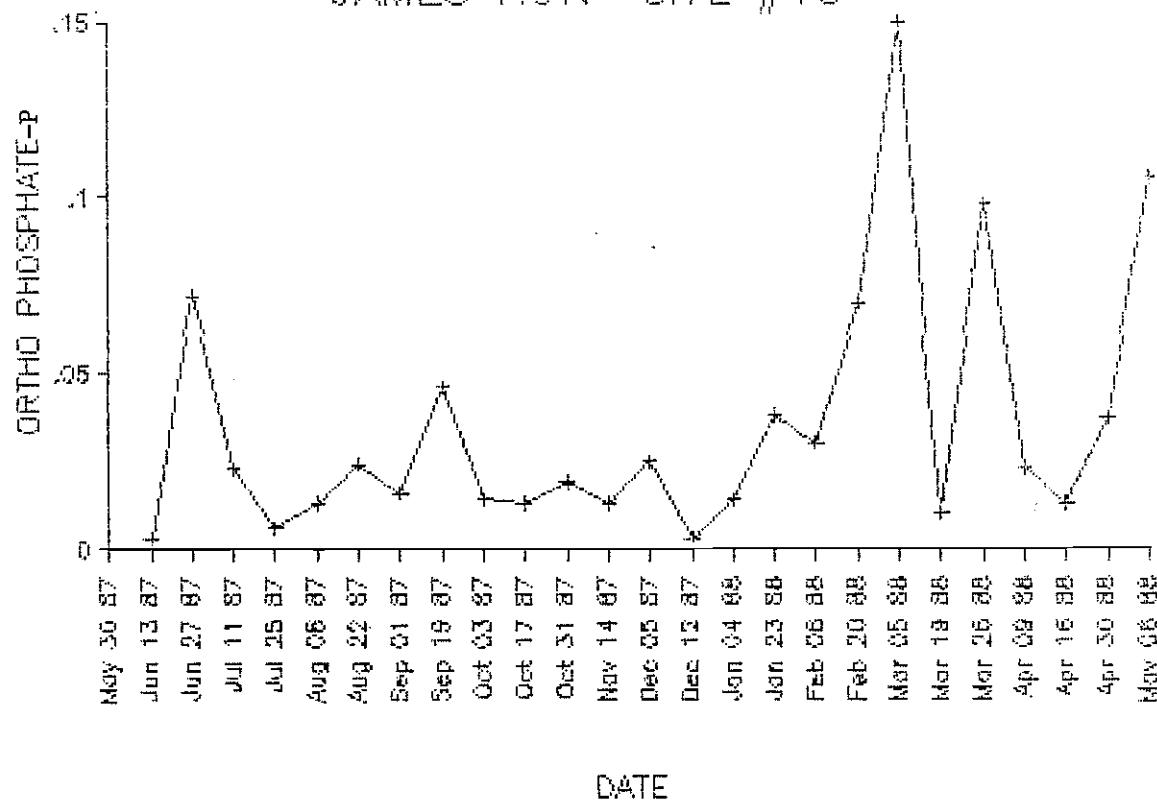
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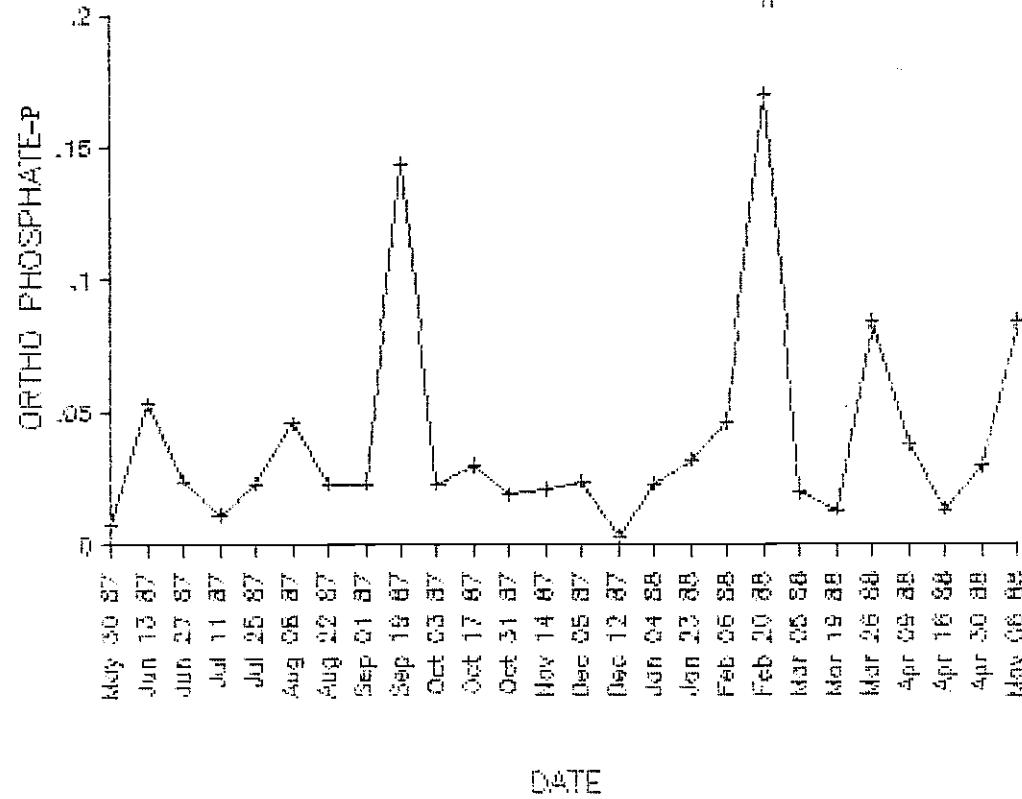
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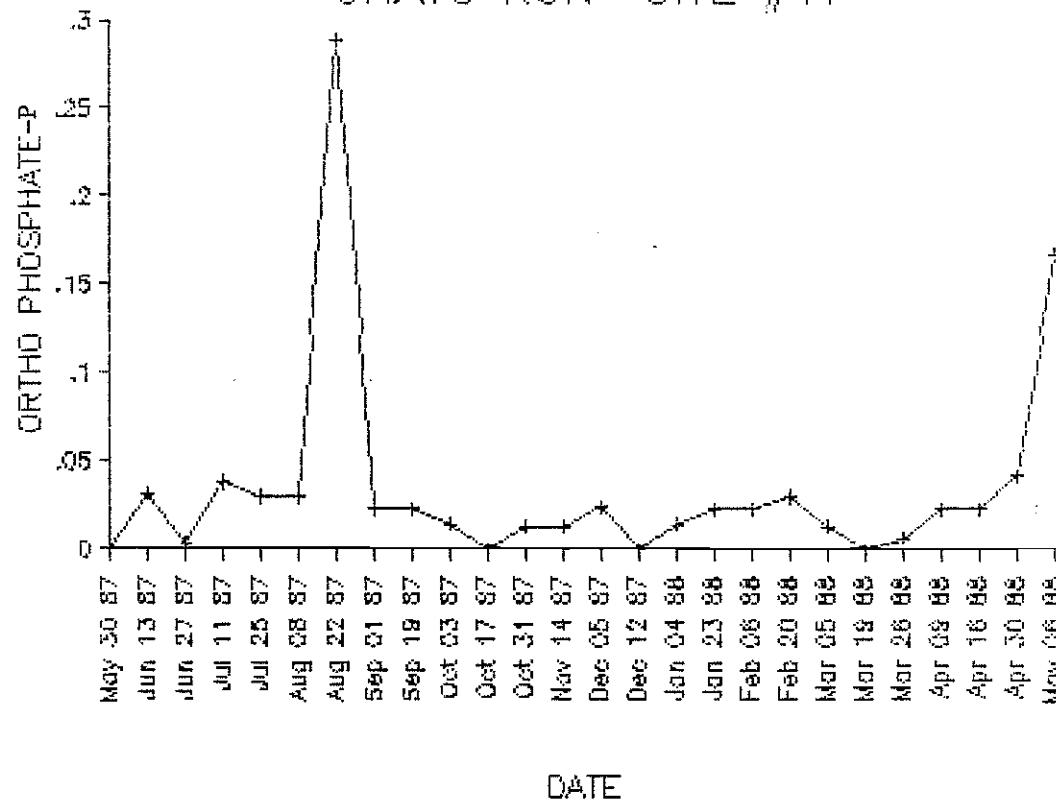
JAMES RUN SITE #15



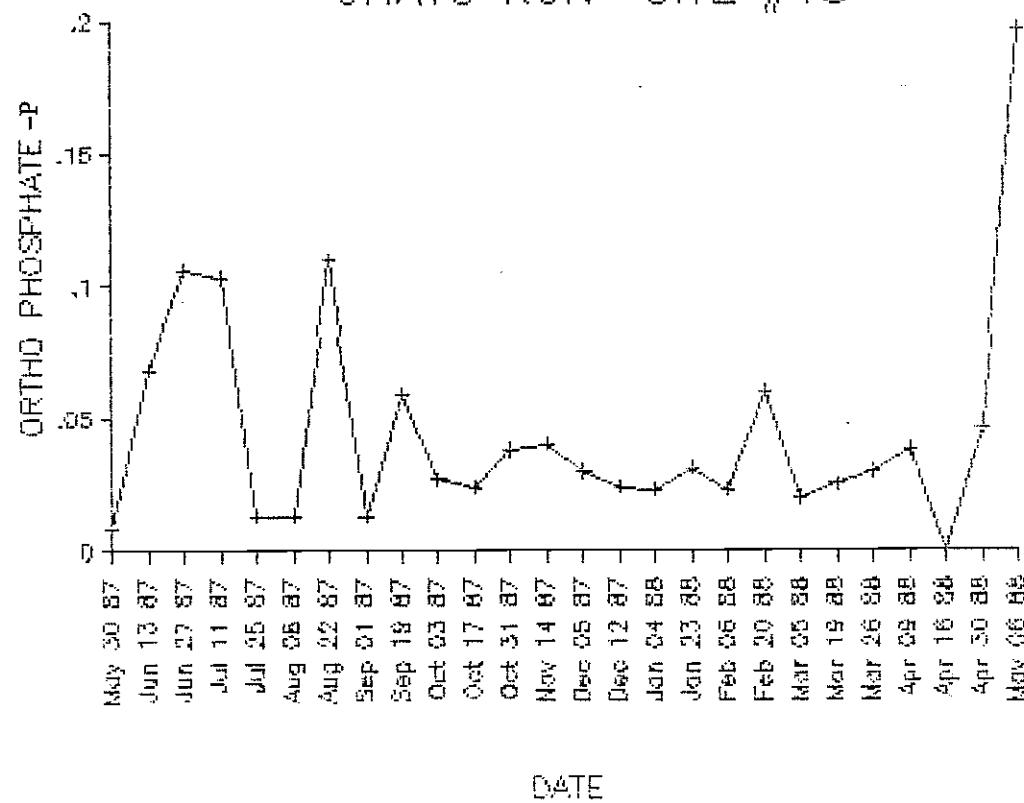
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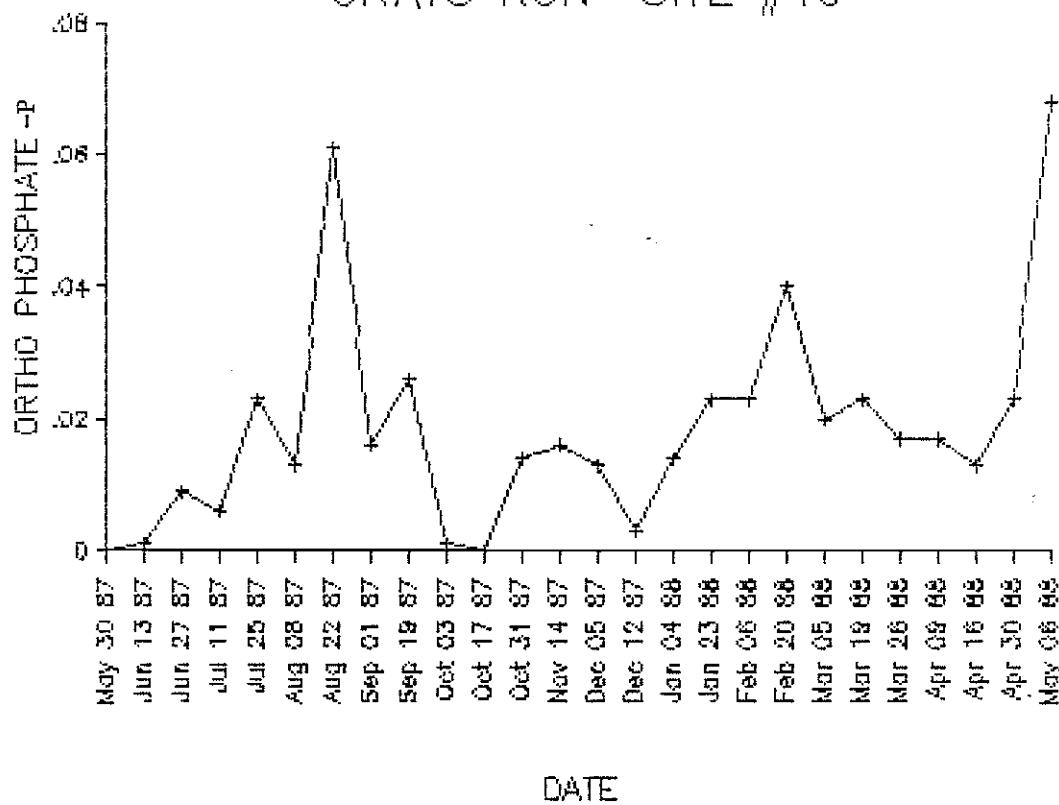
GRAYS RUN SITE #17



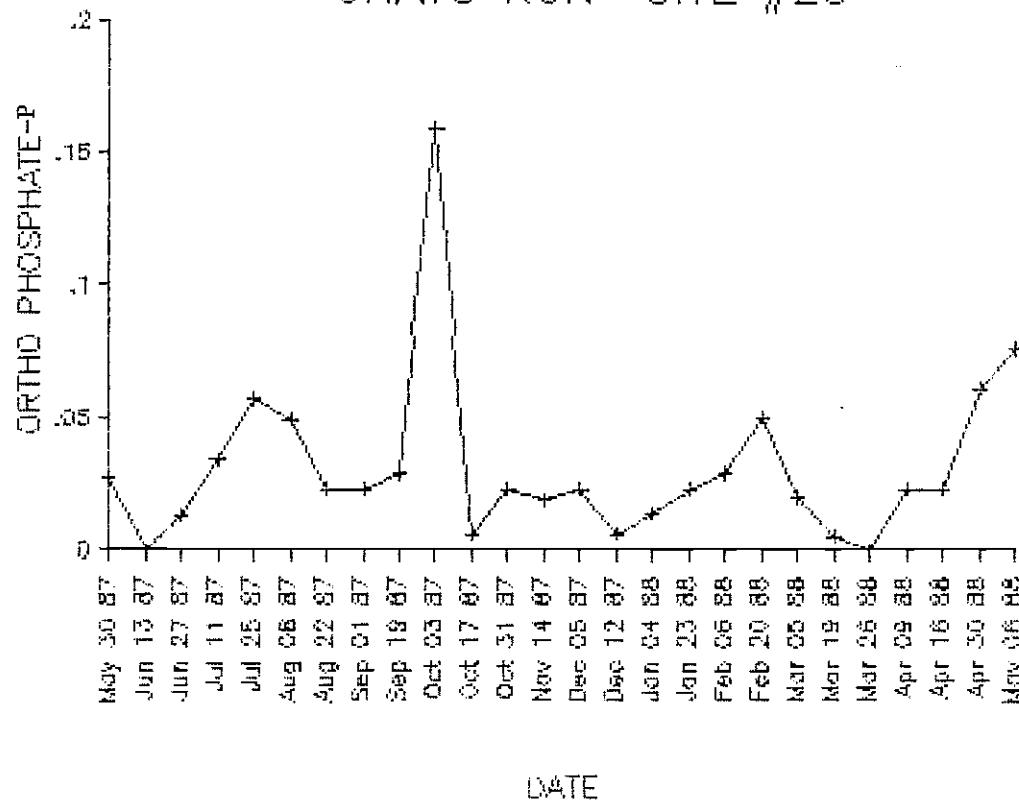
GRAYS RUN SITE #18



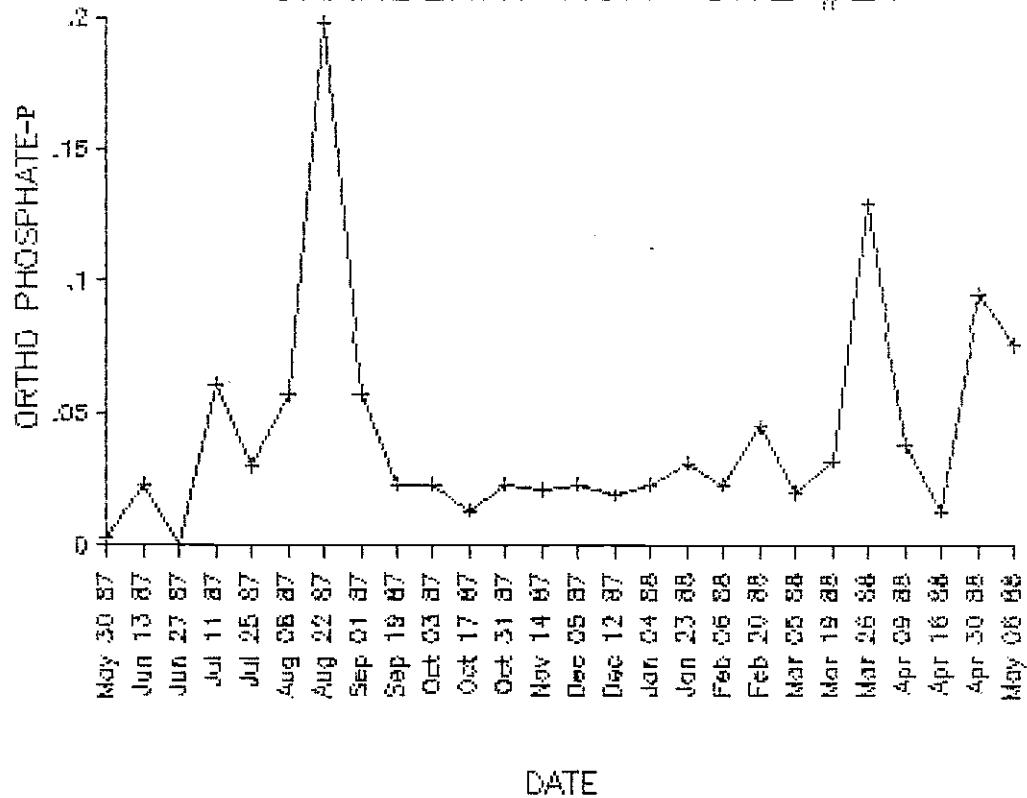
GRAYS RUN SITE #19



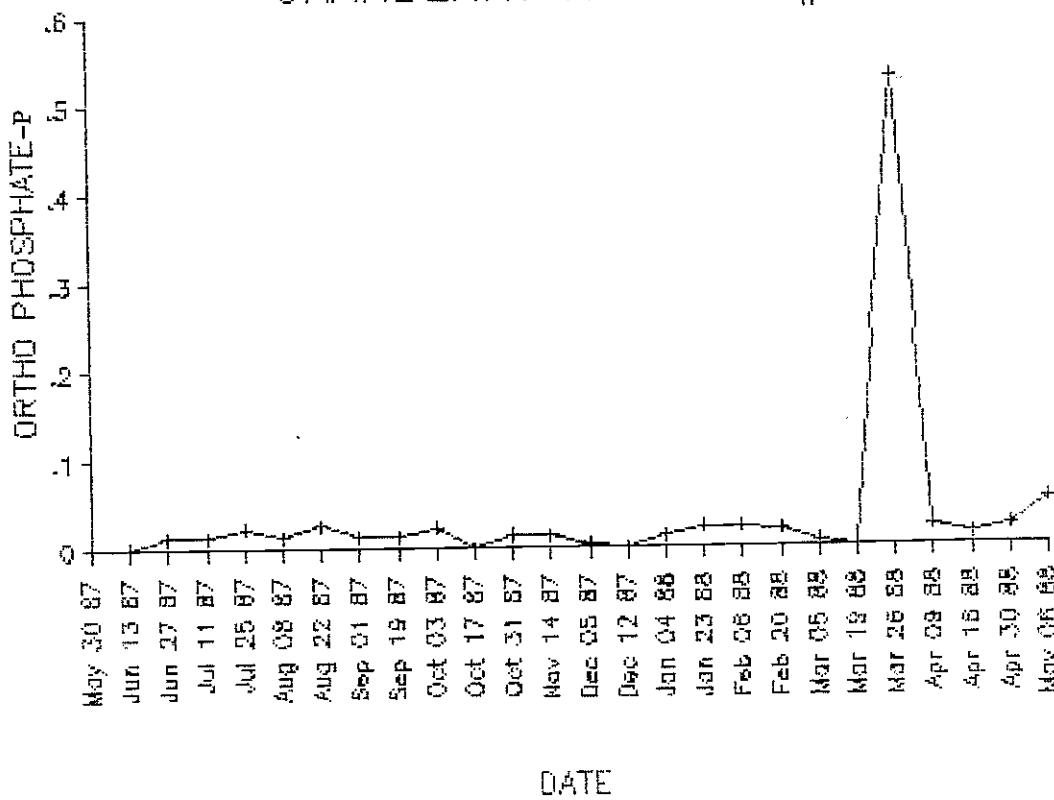
GRAYS RUN SITE #20



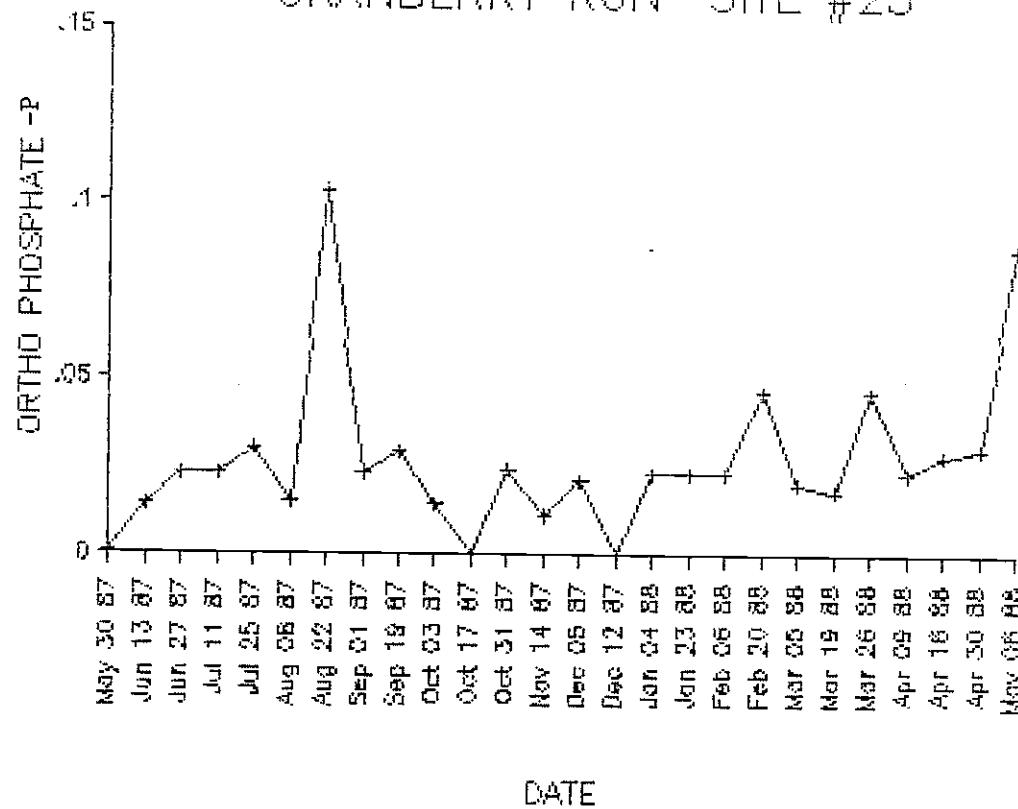
CRANBERRY RUN SITE #21



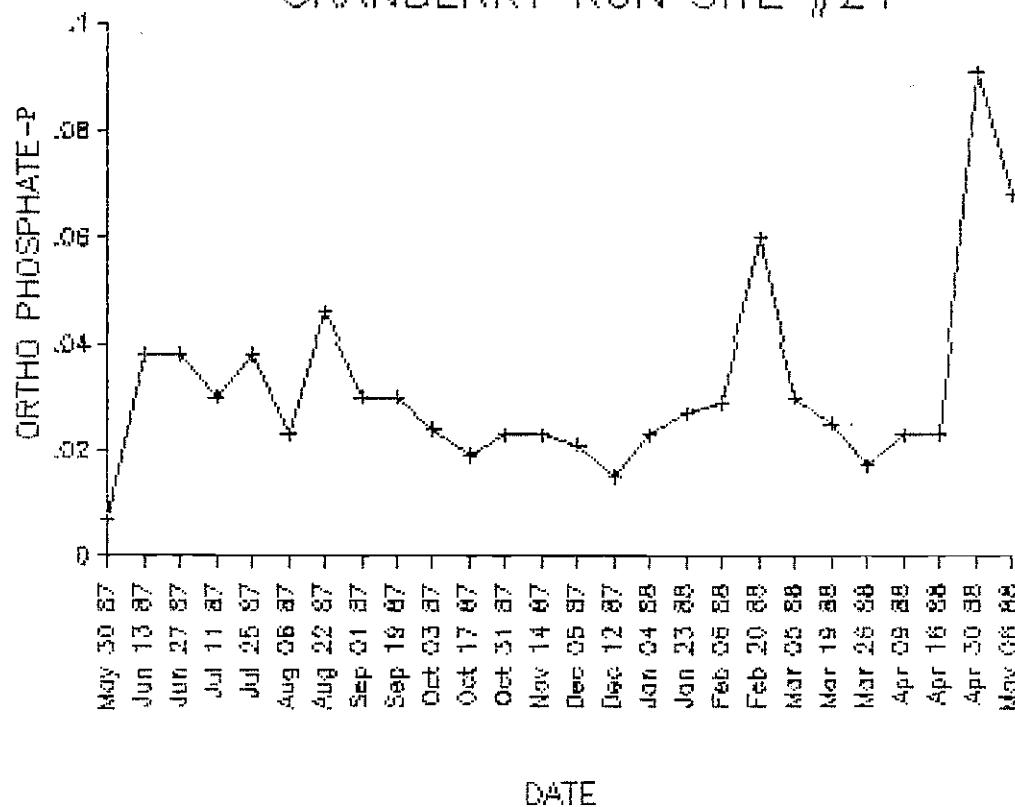
CRANBERRY RUN SITE #22



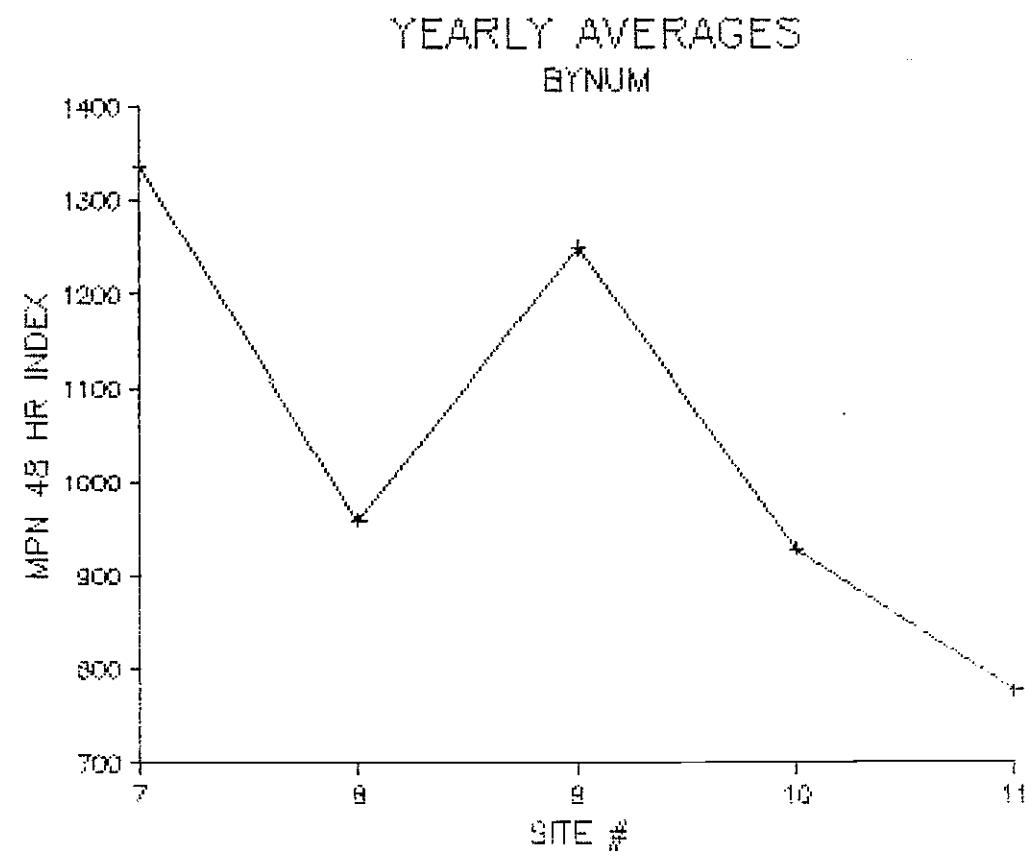
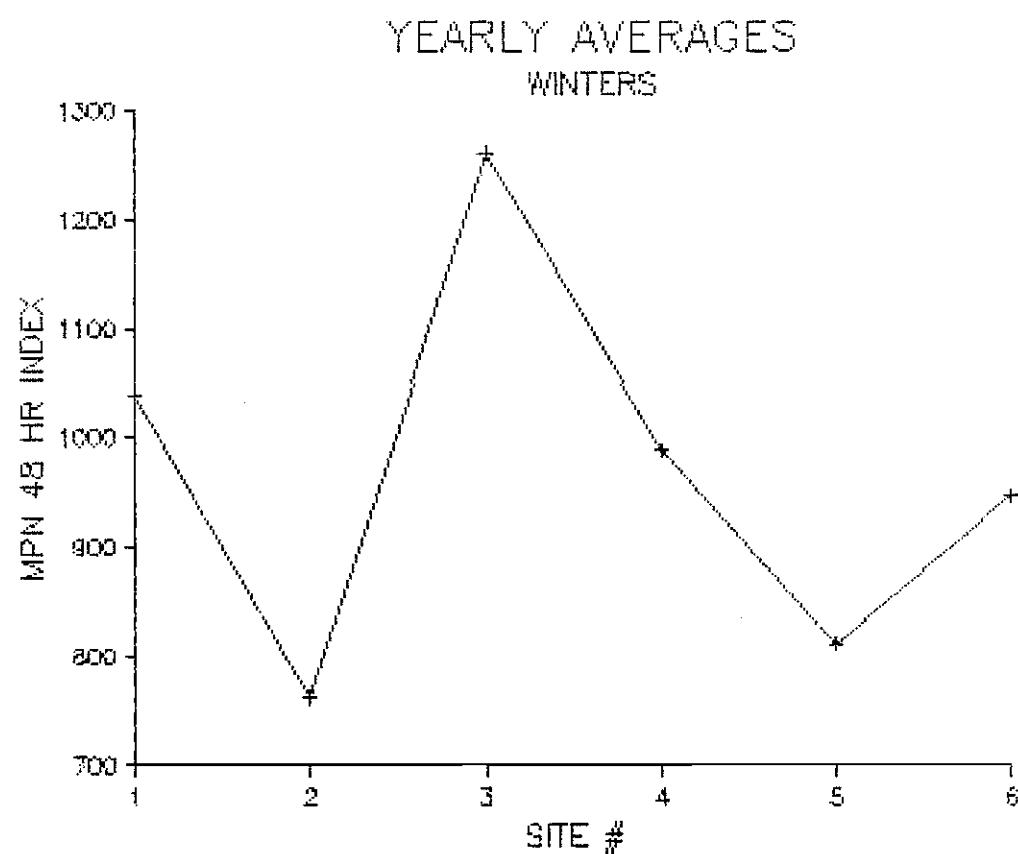
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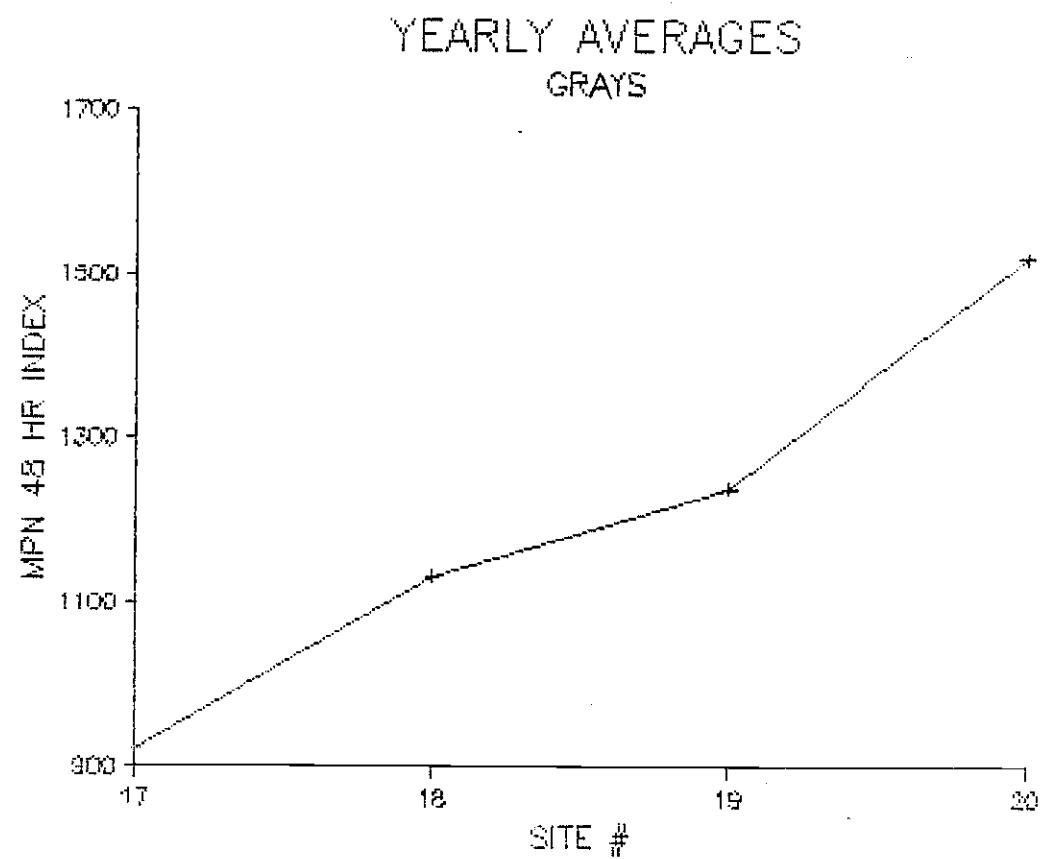
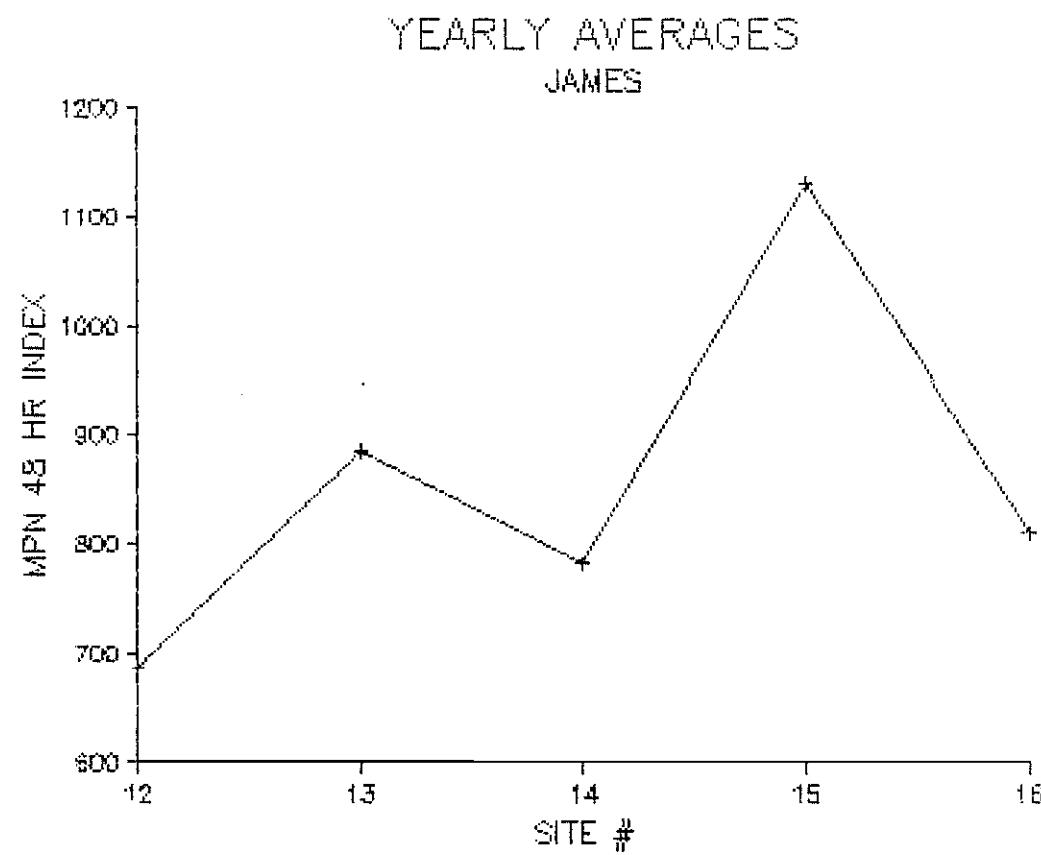


CRANBERRY RUN SITE #24

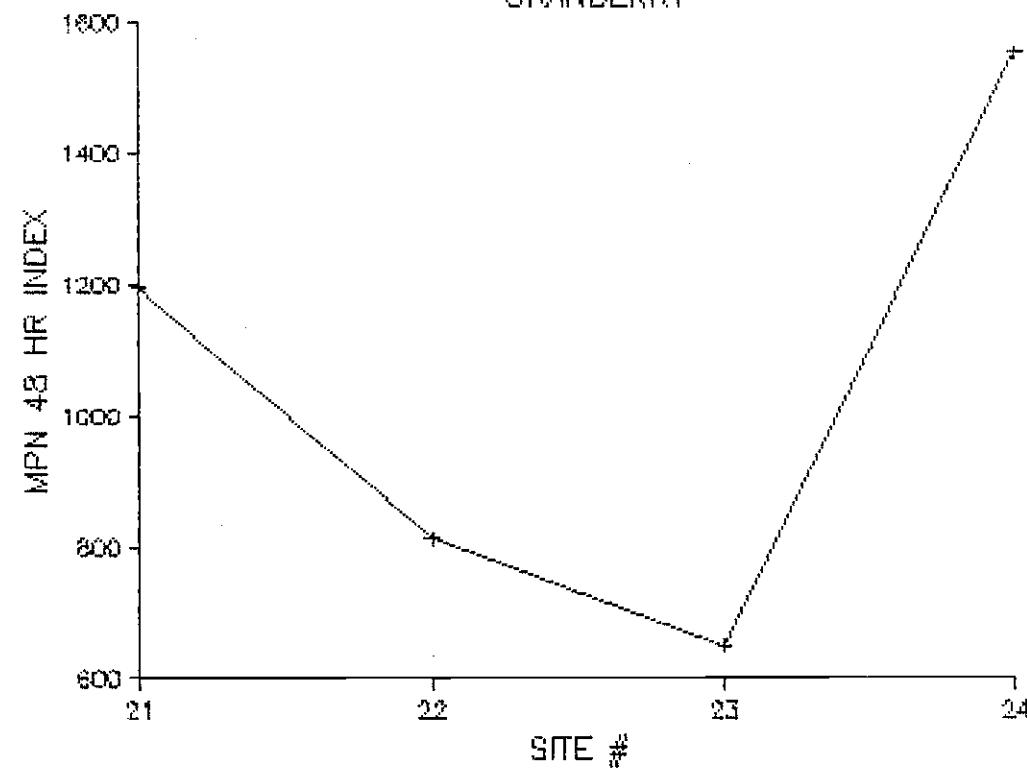


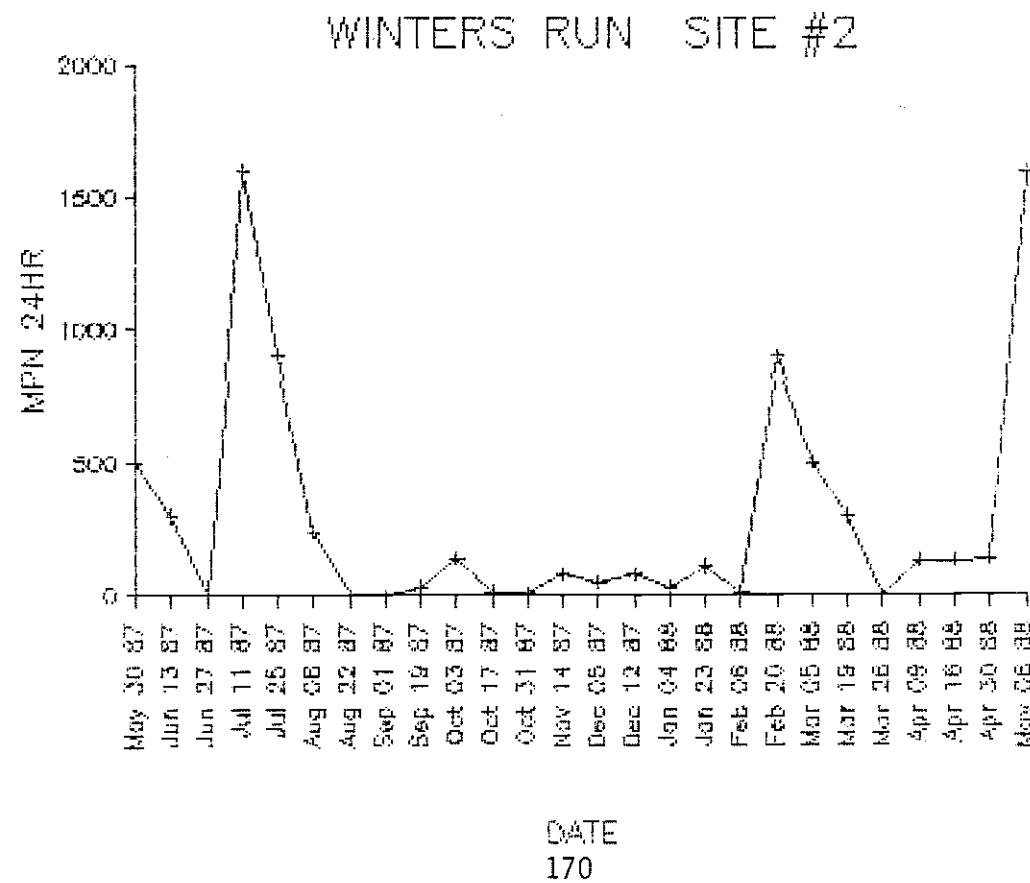
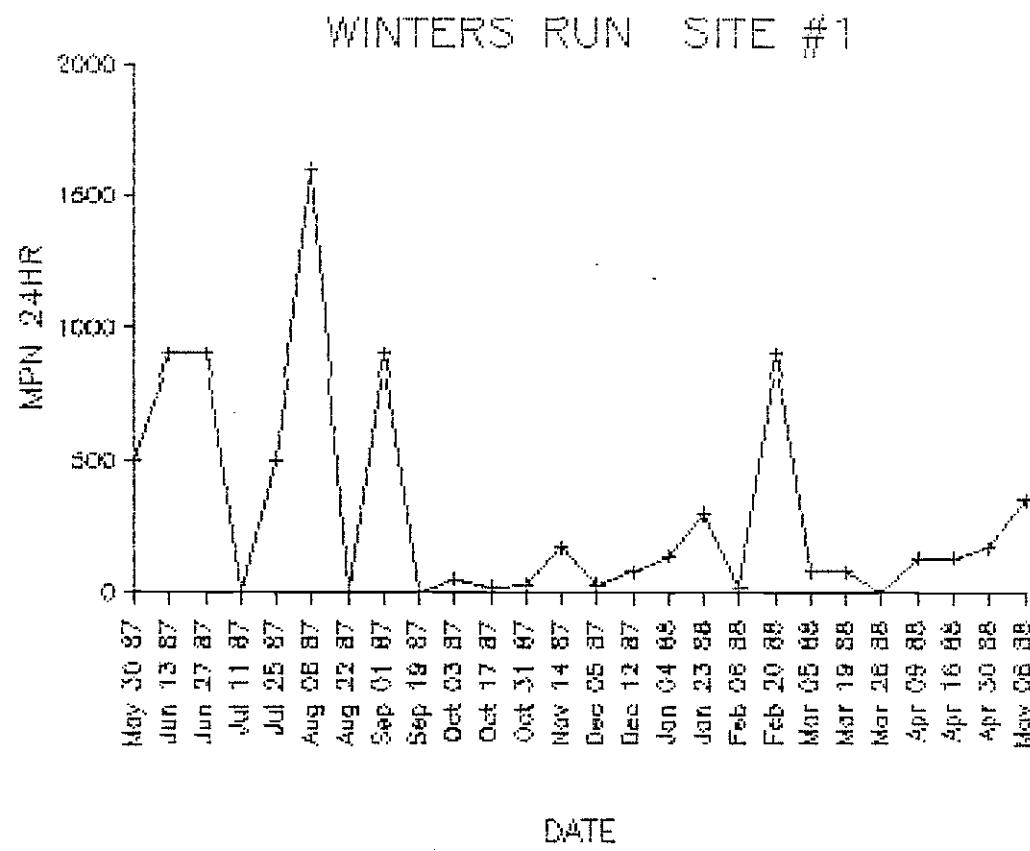
MPN 24HR





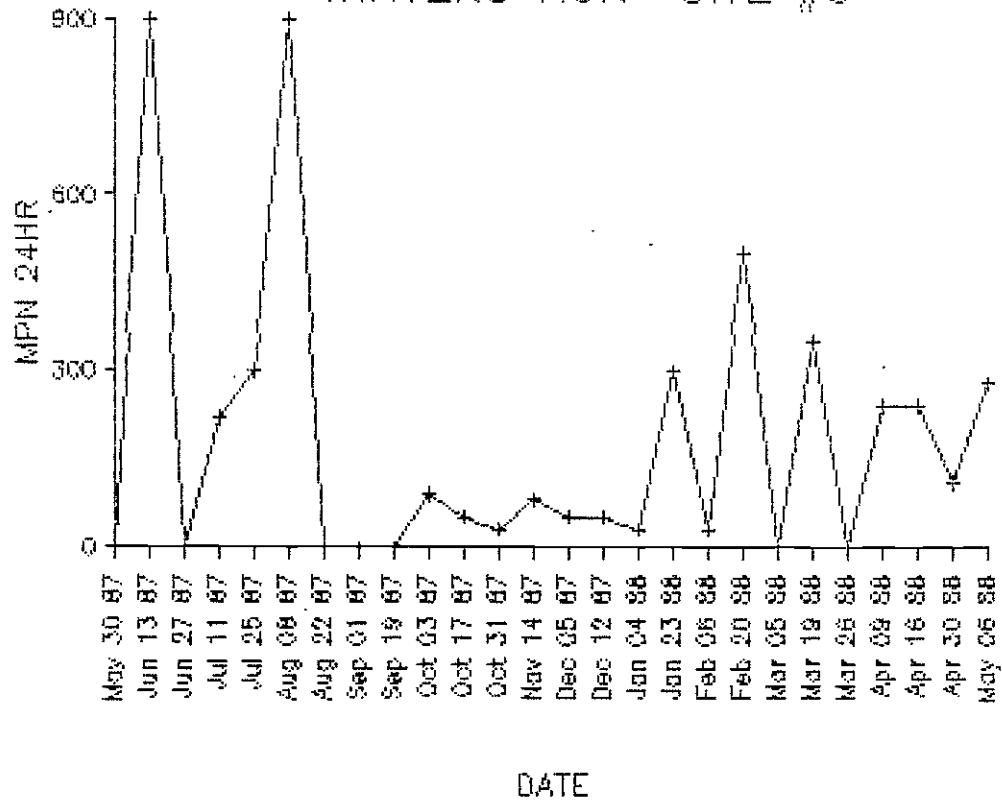
YEARLY AVERAGES
CRANBERRY



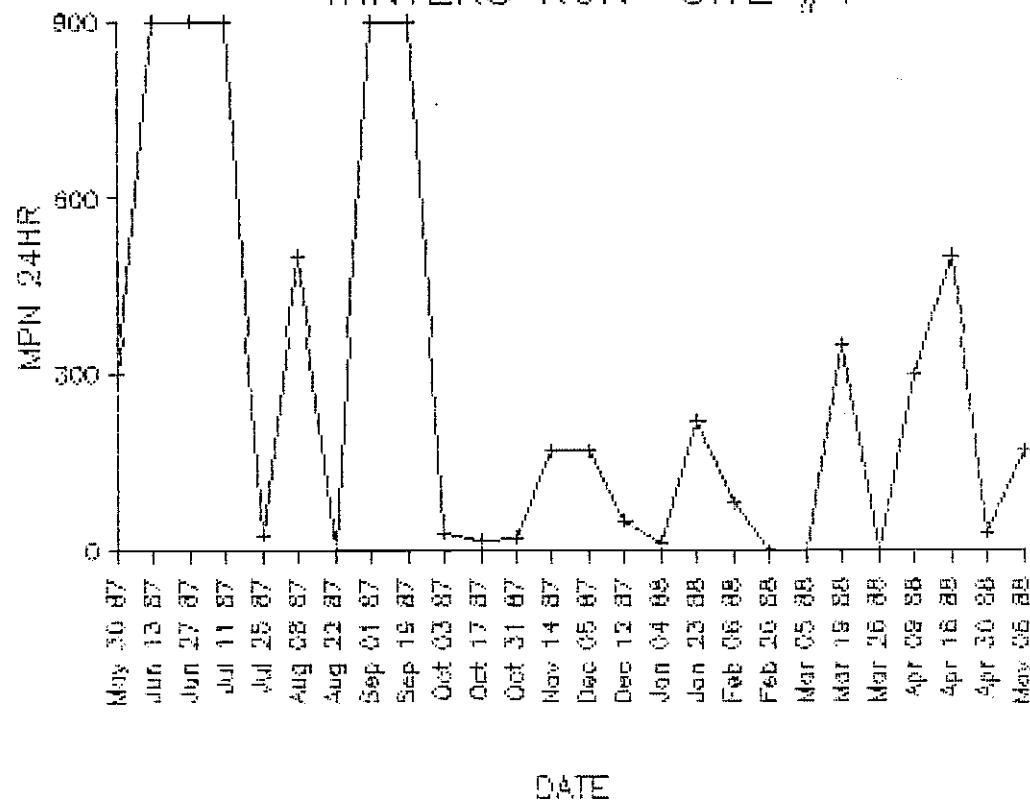


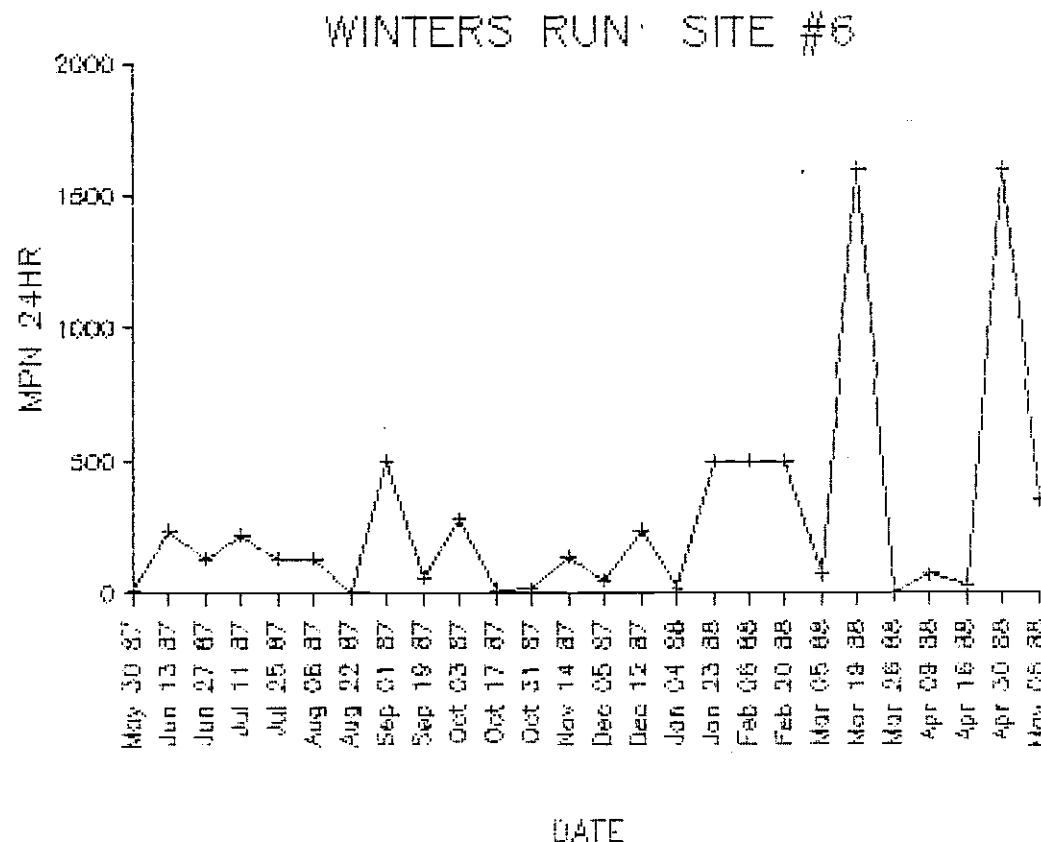
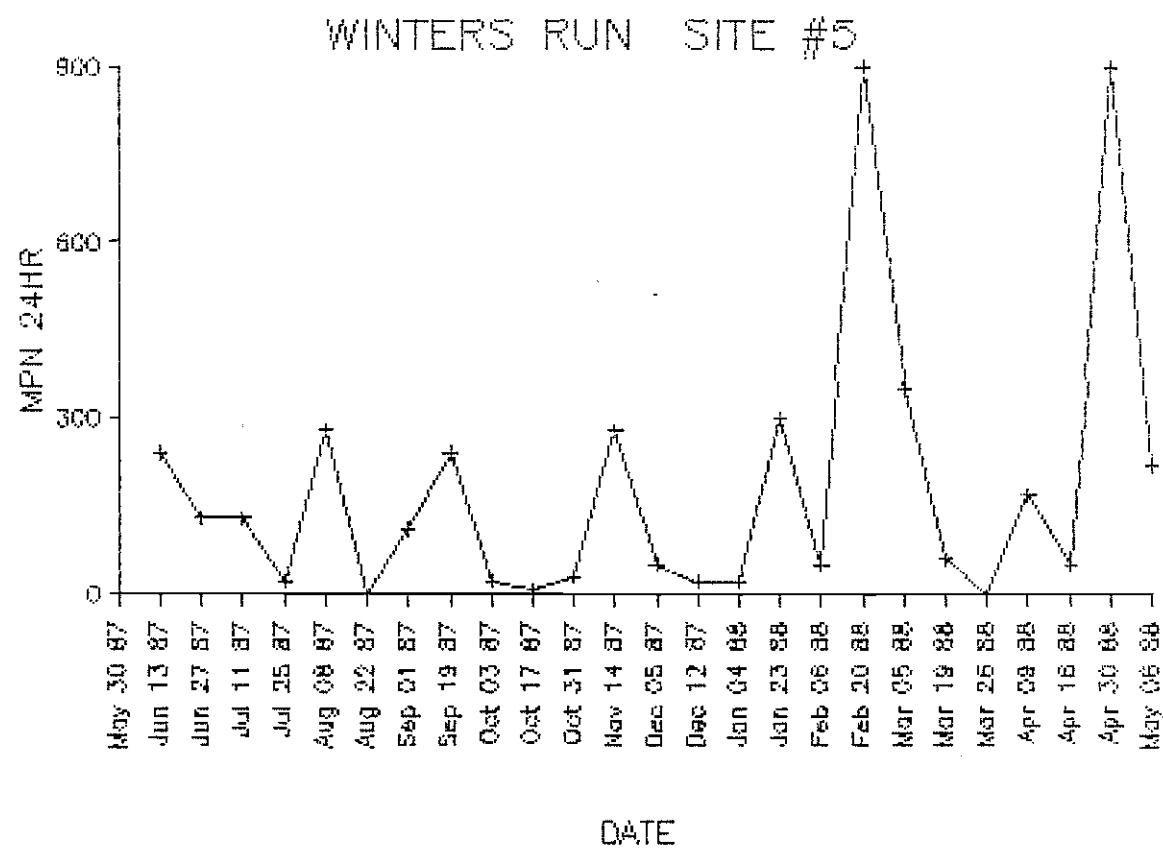
DATE
170

WINTERS RUN SITE #3

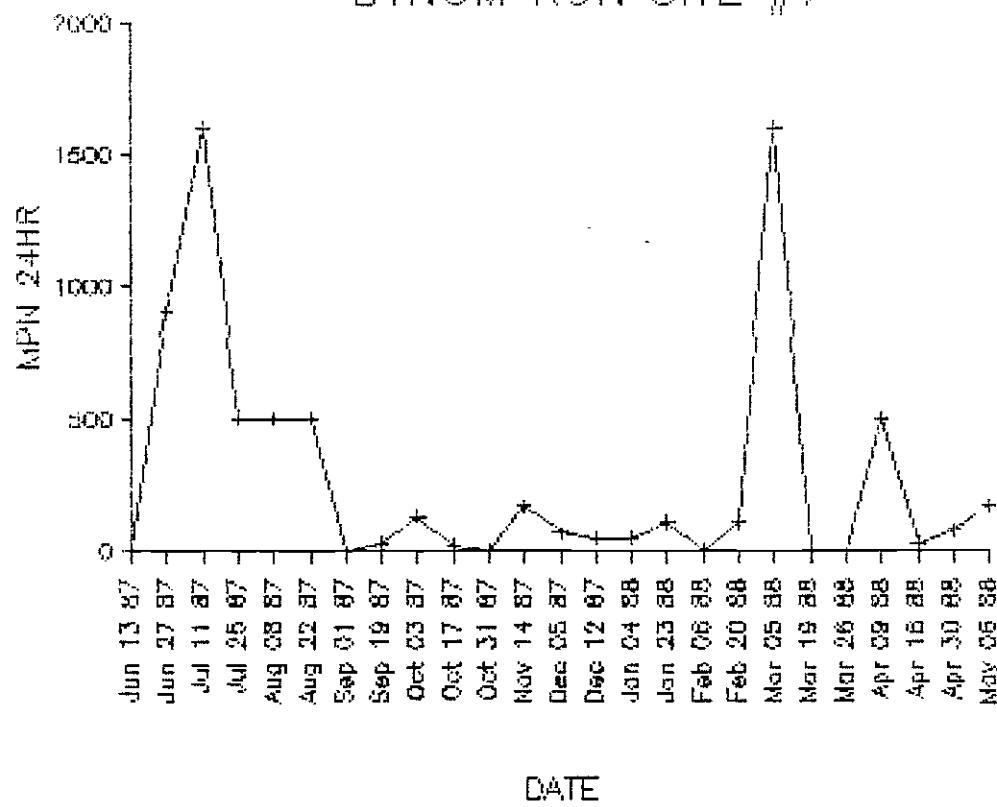


WINTERS RUN SITE #4

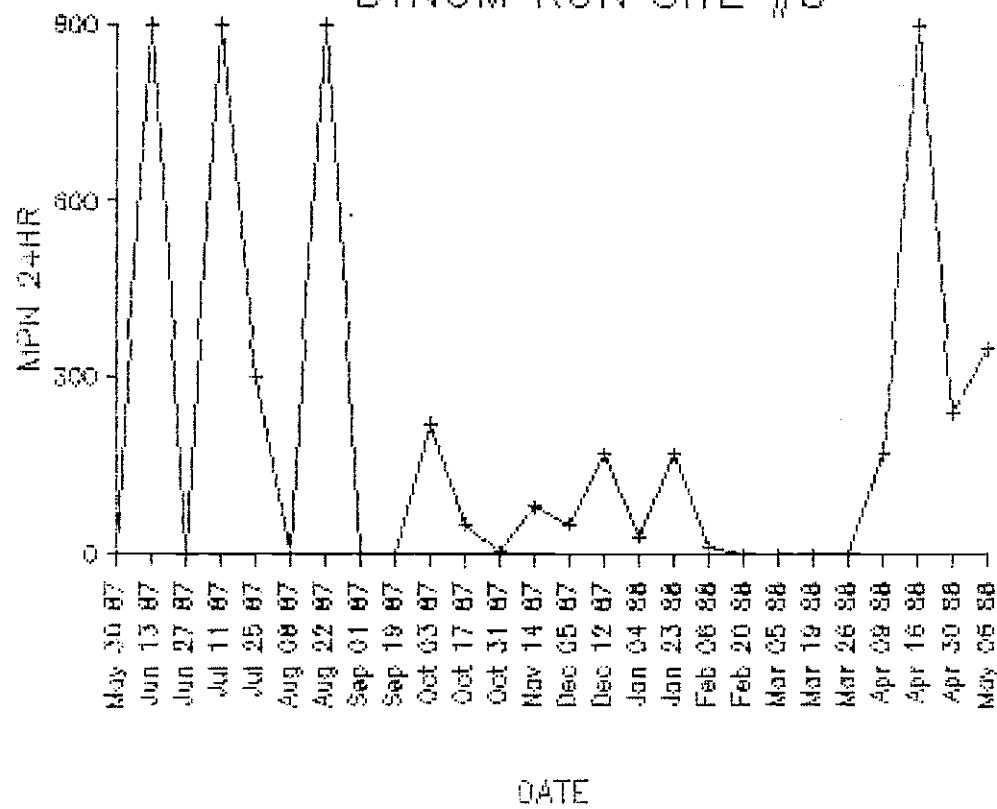




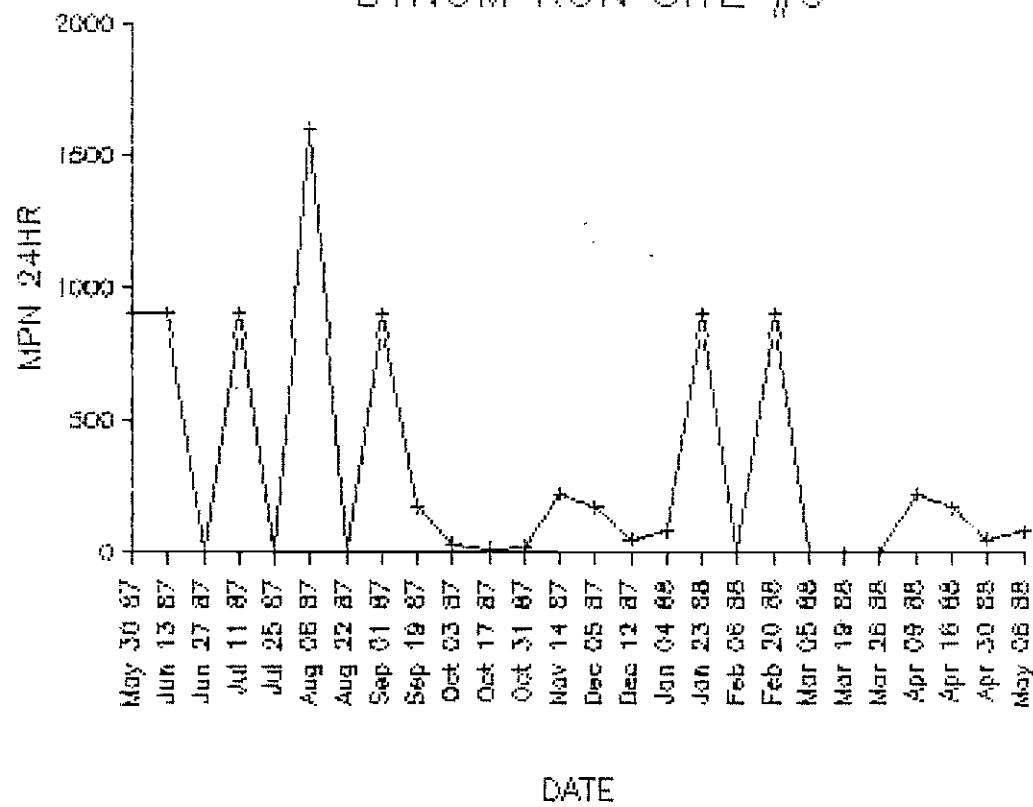
BYNUM RUN SITE #7



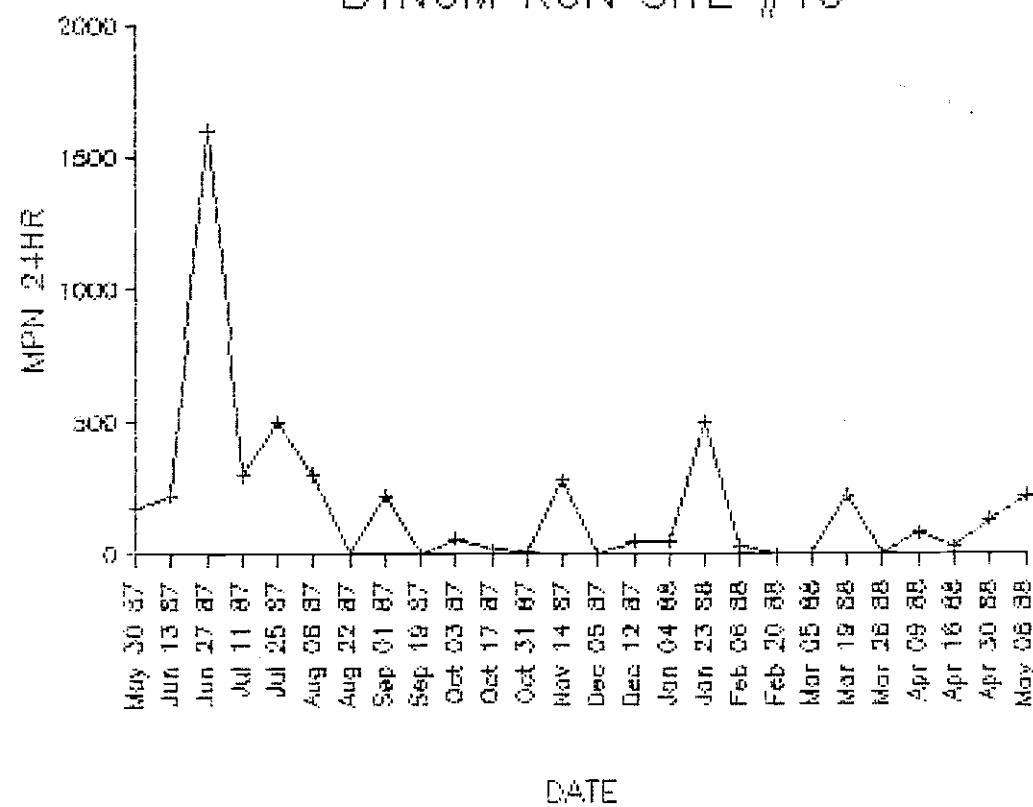
BYNUM RUN SITE #80



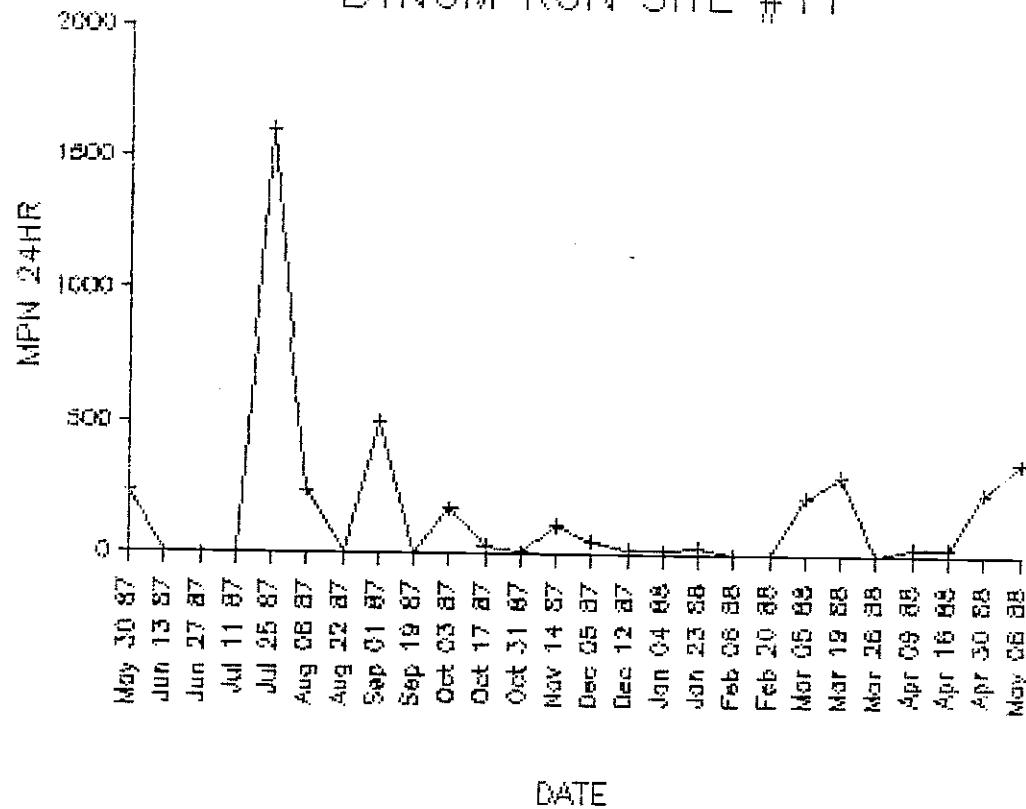
BYNUM RUN SITE #9



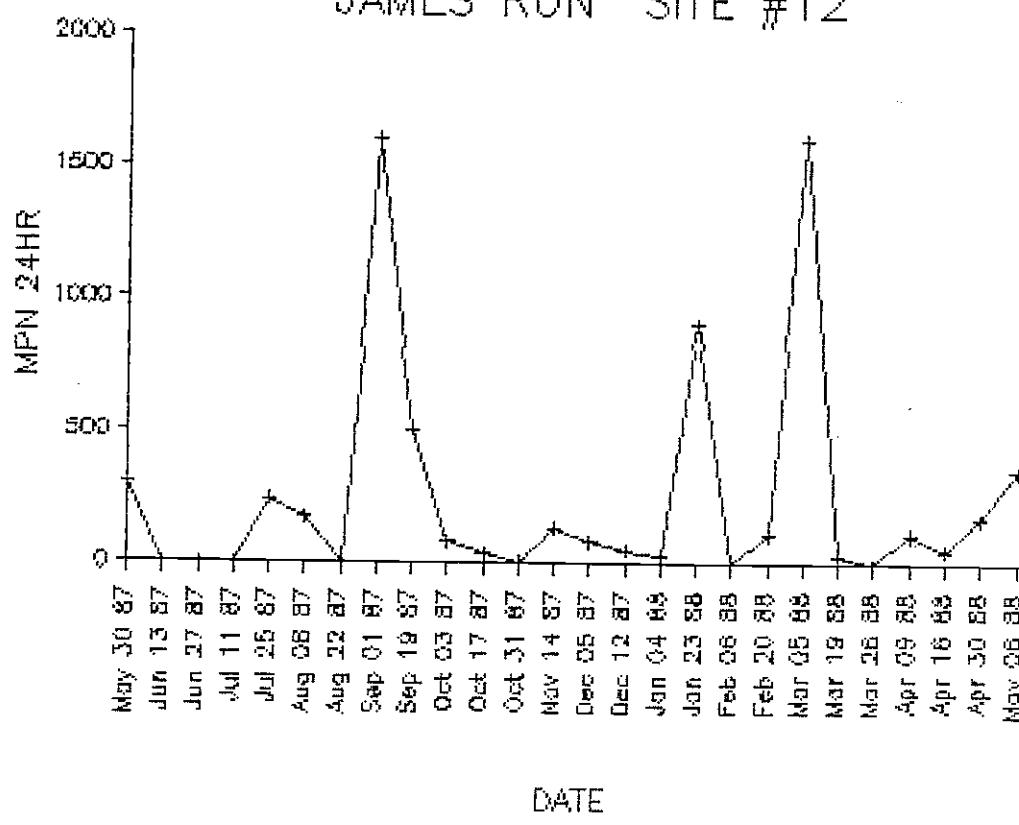
BYNUM RUN SITE #10

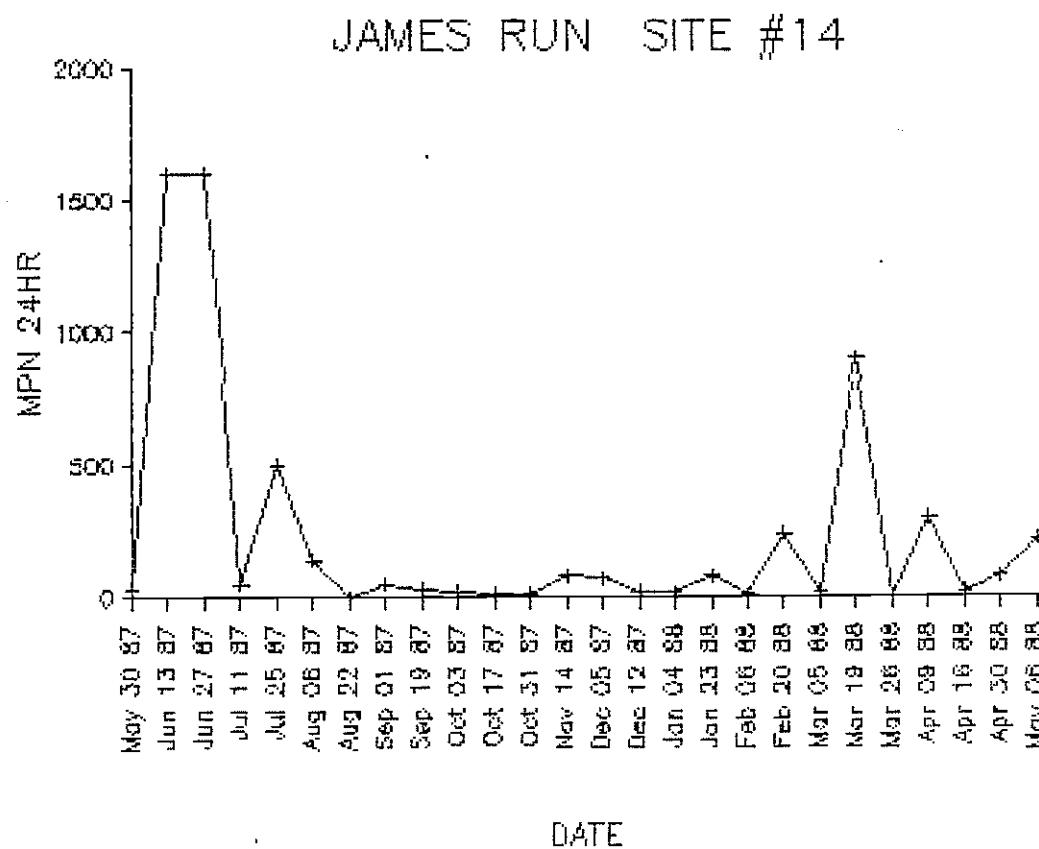
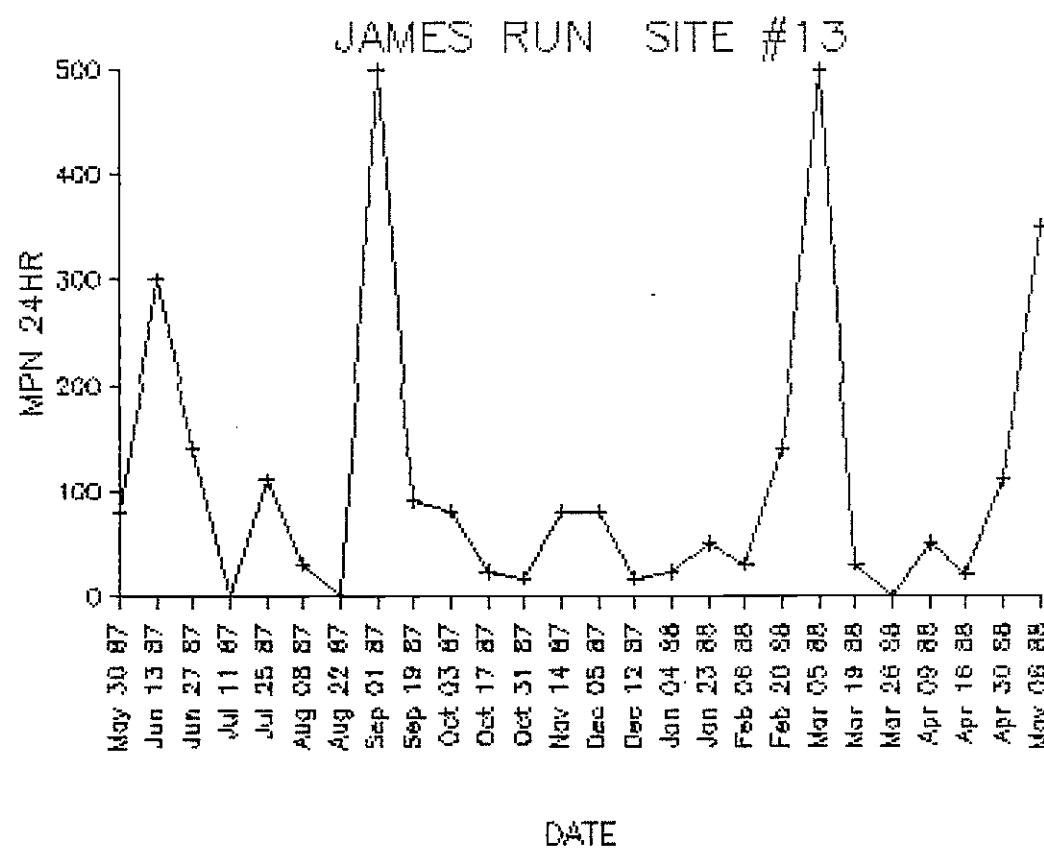


SYNUM RUN SITE #11

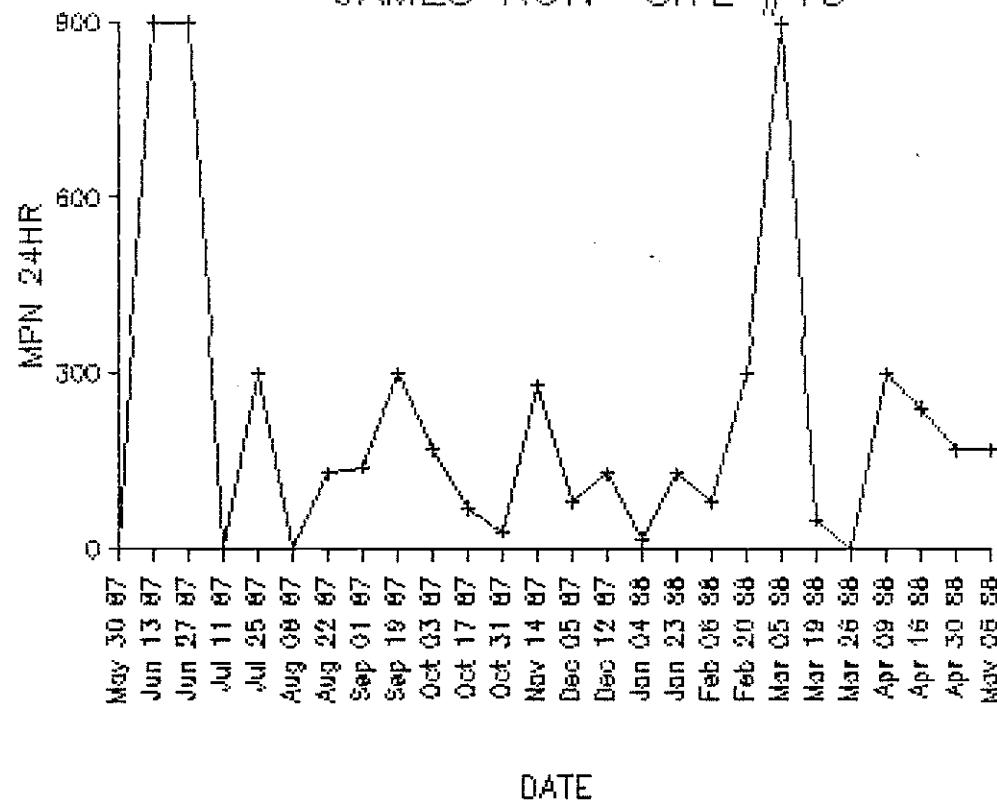


JAMES RUN SITE #12

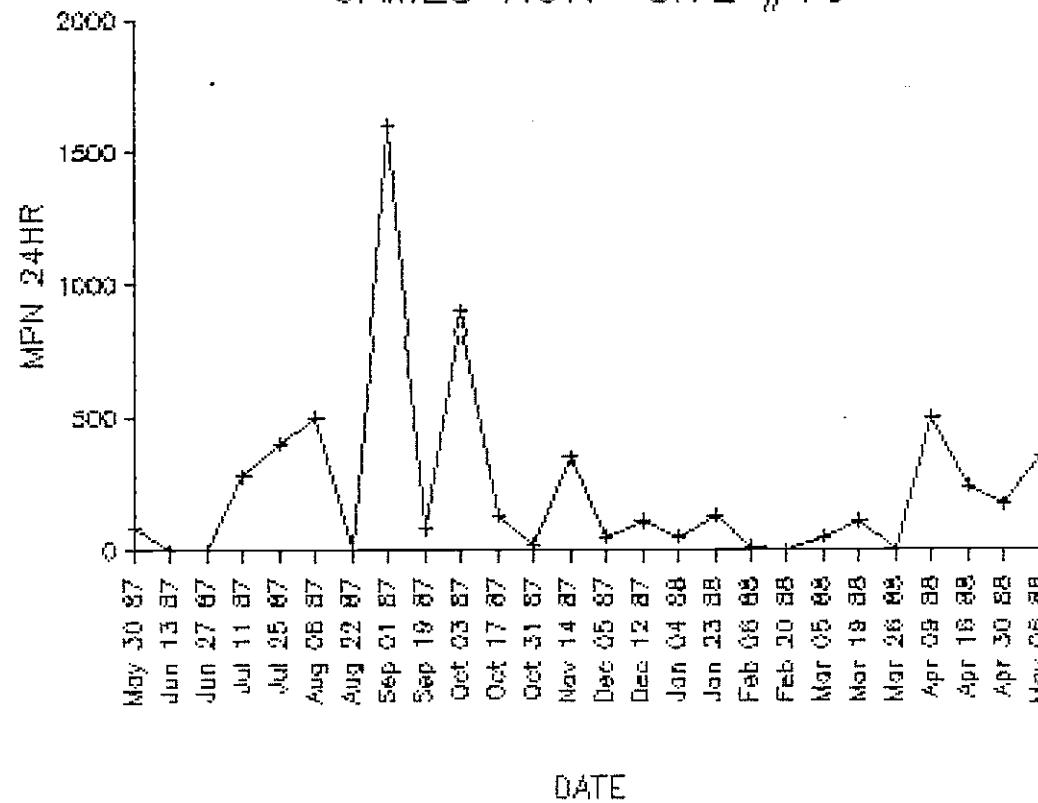




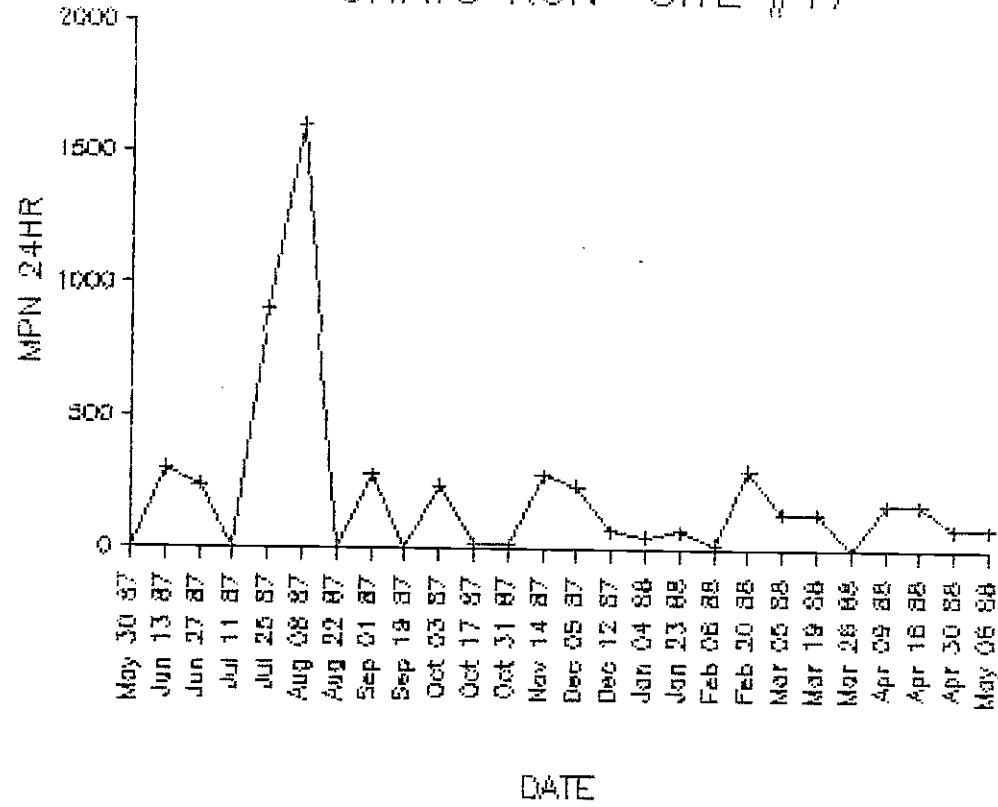
JAMES RUN SITE #15



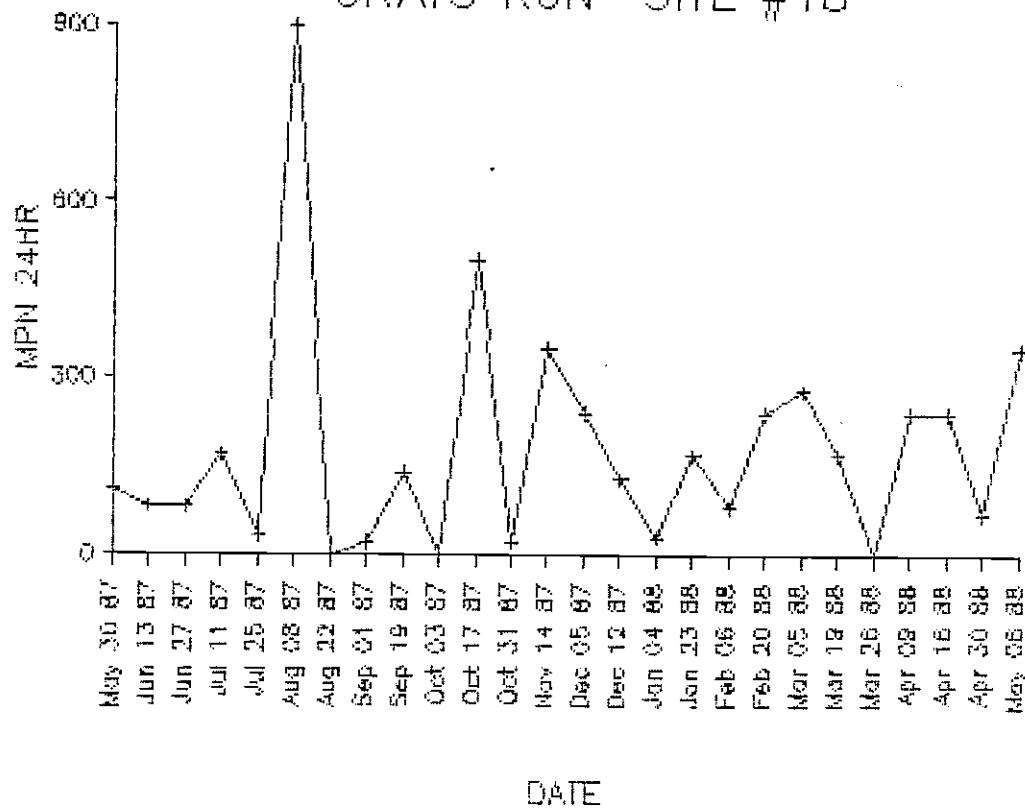
JAMES RUN SITE #16



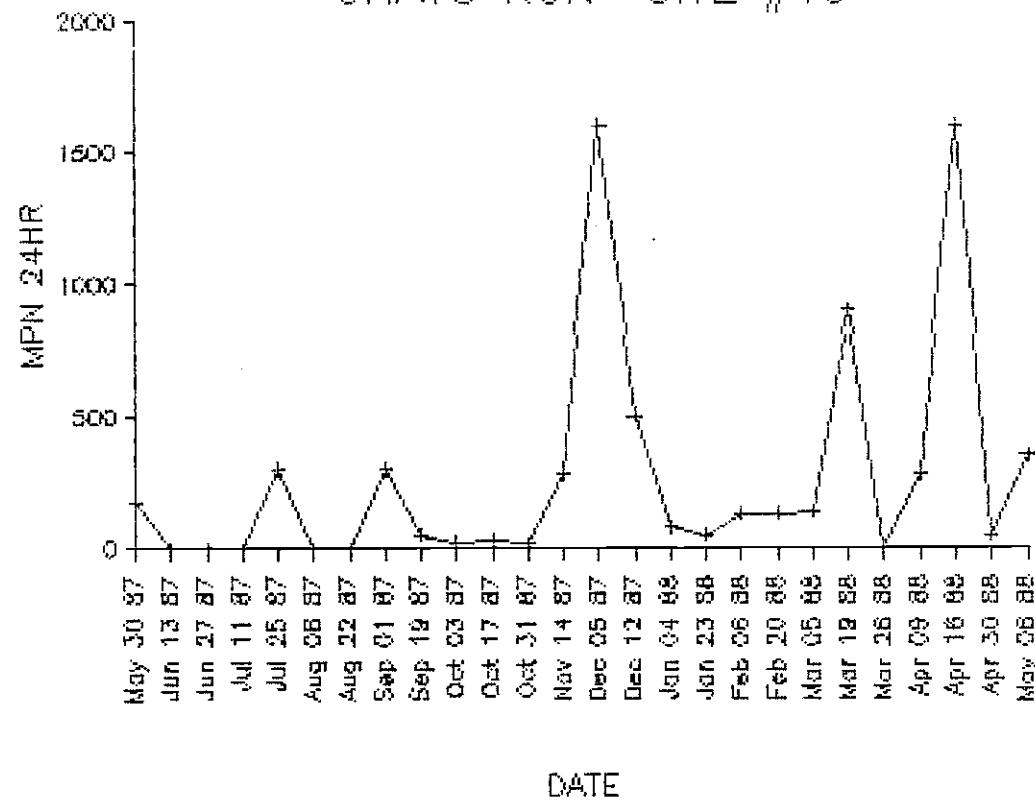
GRAYS RUN SITE #17



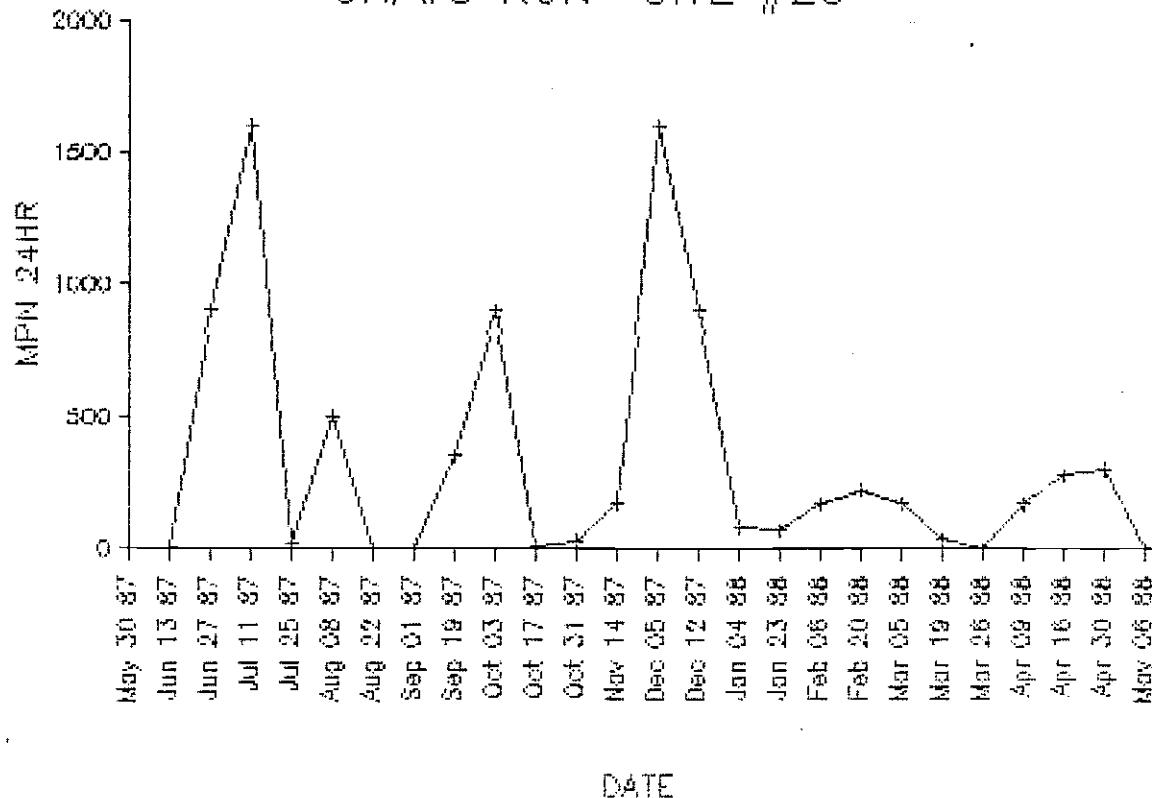
GRAYS RUN SITE #18



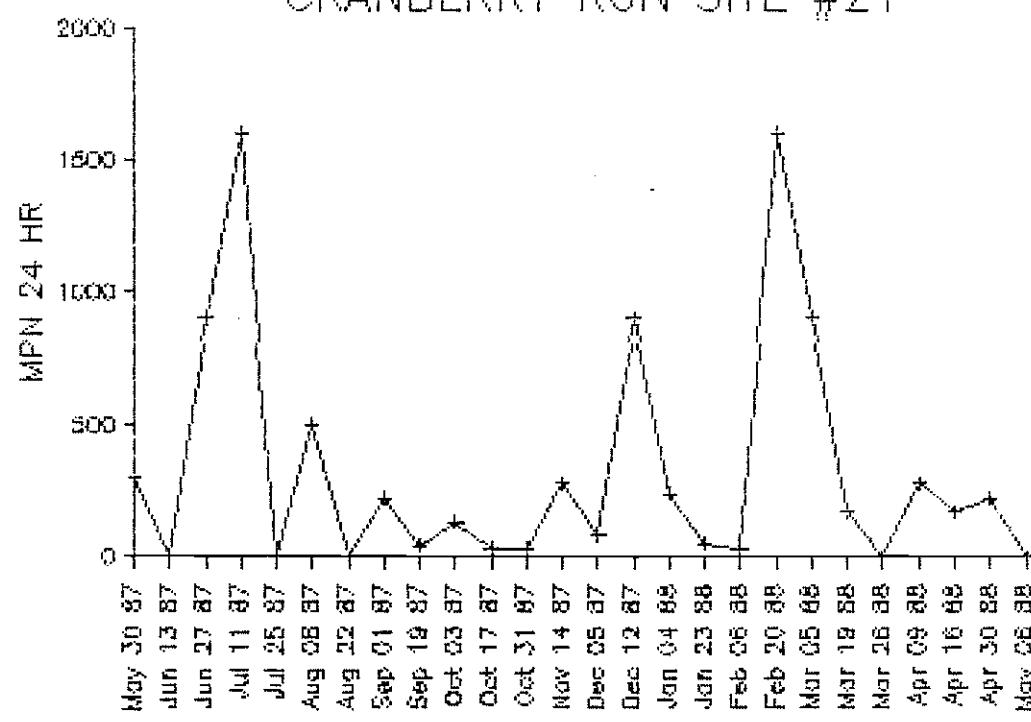
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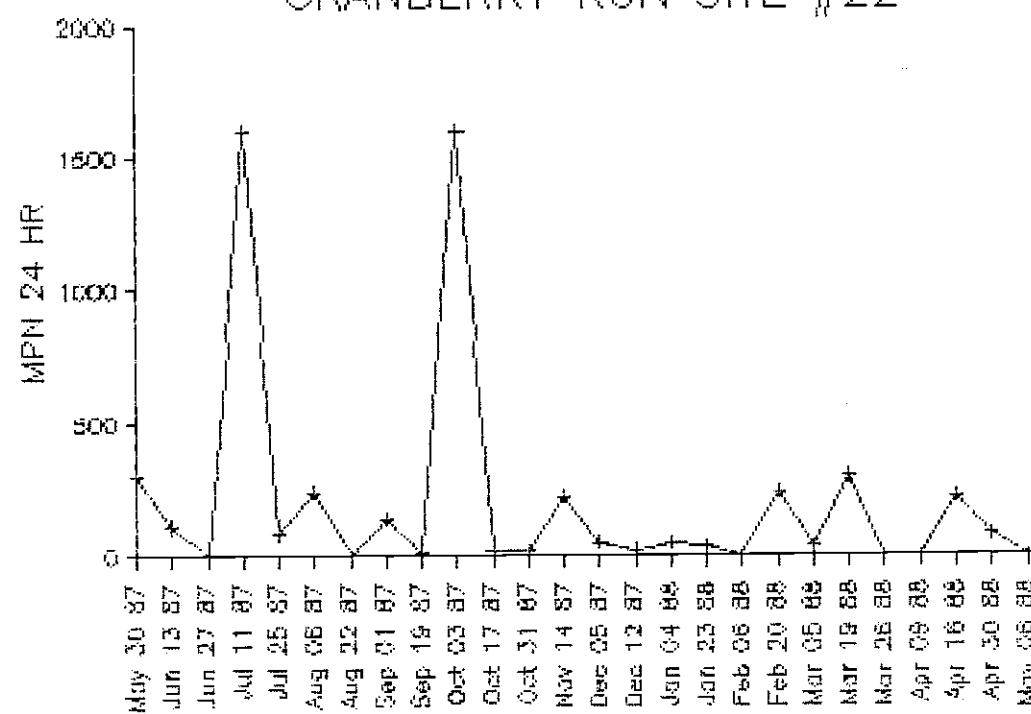
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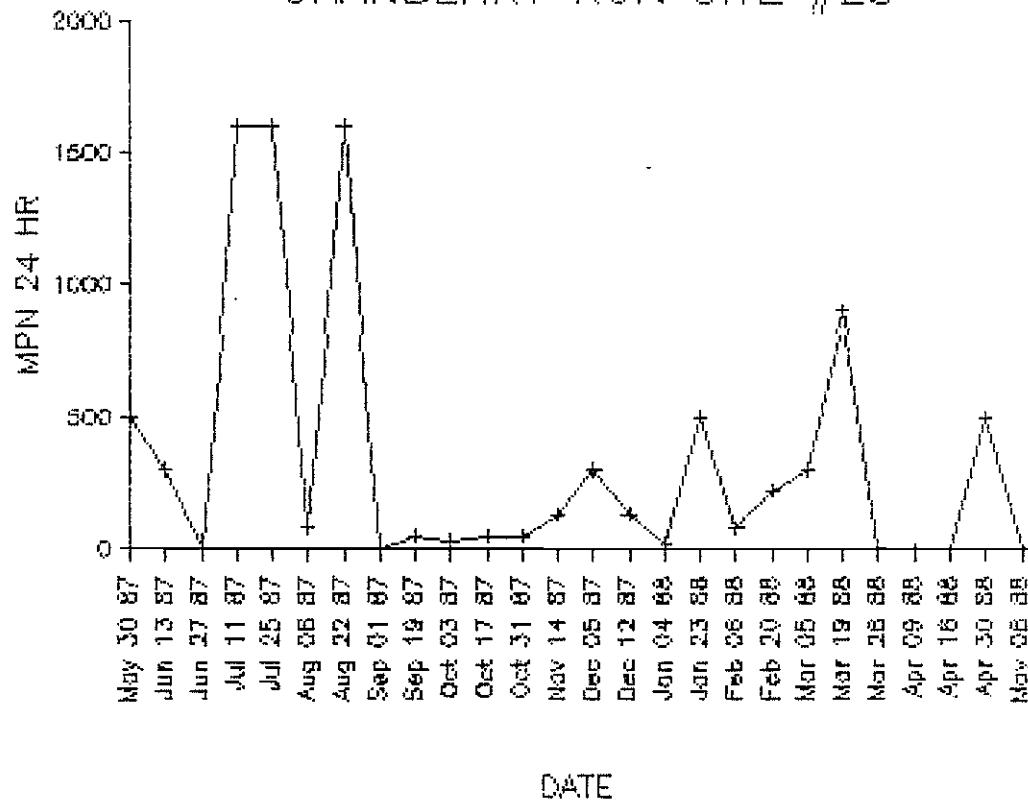
CRANBERRY RUN SITE #21



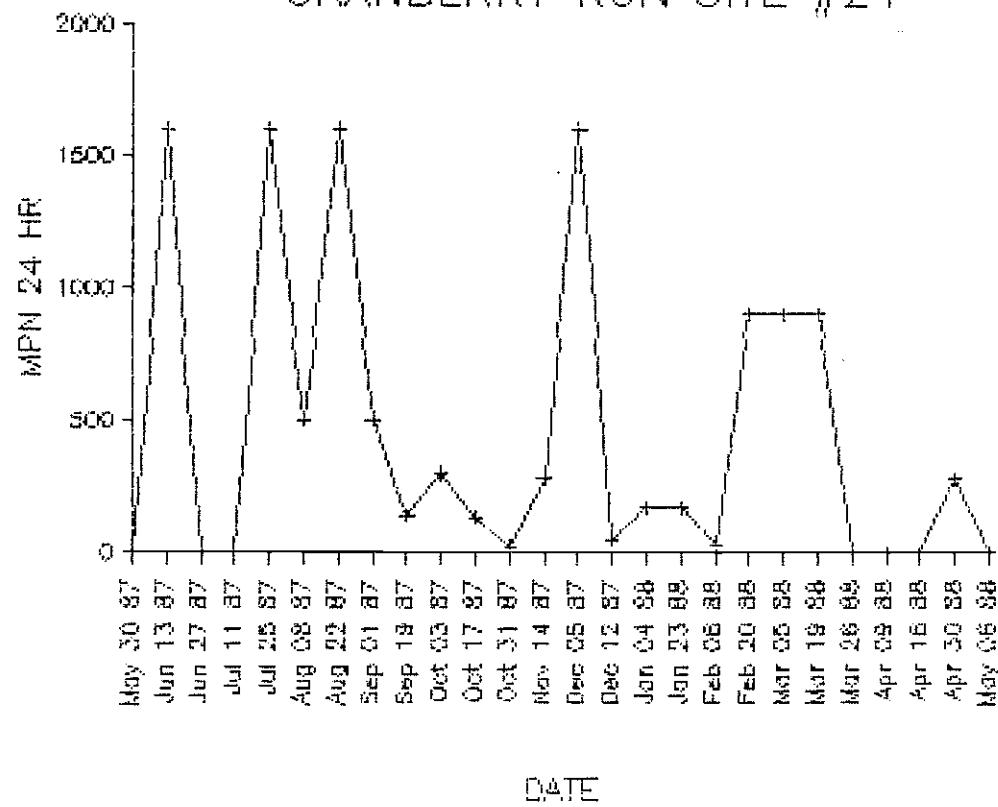
CRANBERRY RUN SITE #22



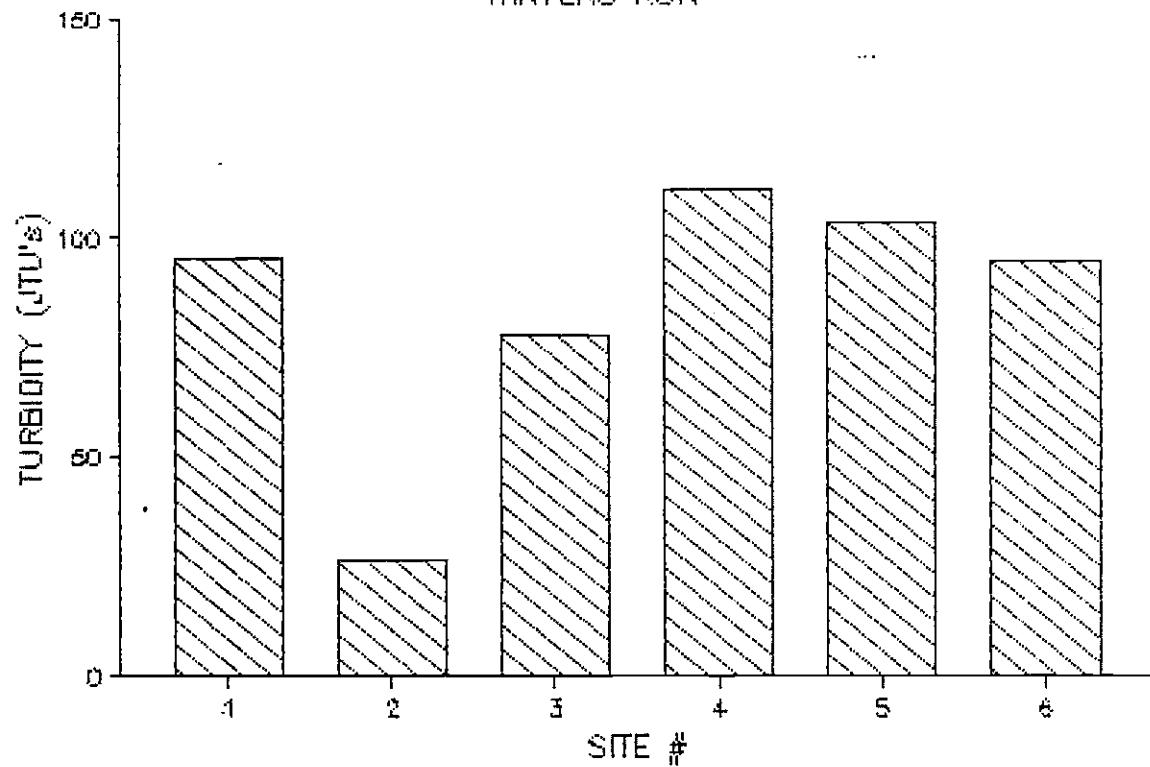
CRANBERRY RUN SITE #23



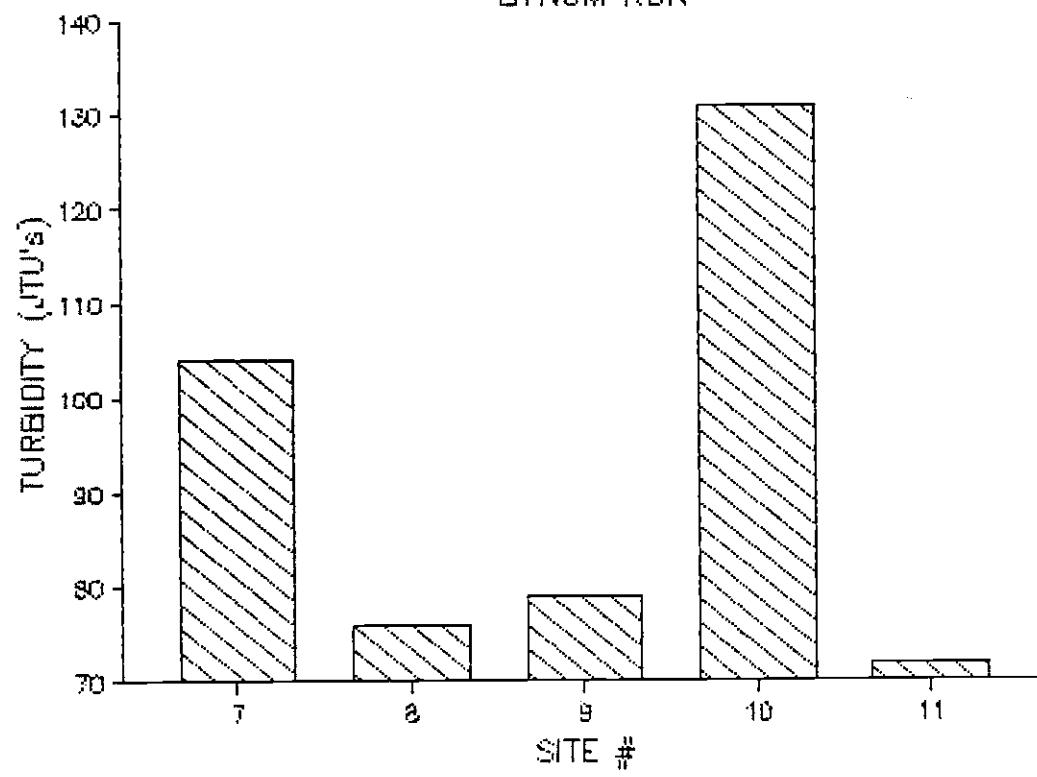
CRANBERRY RUN SITE #24



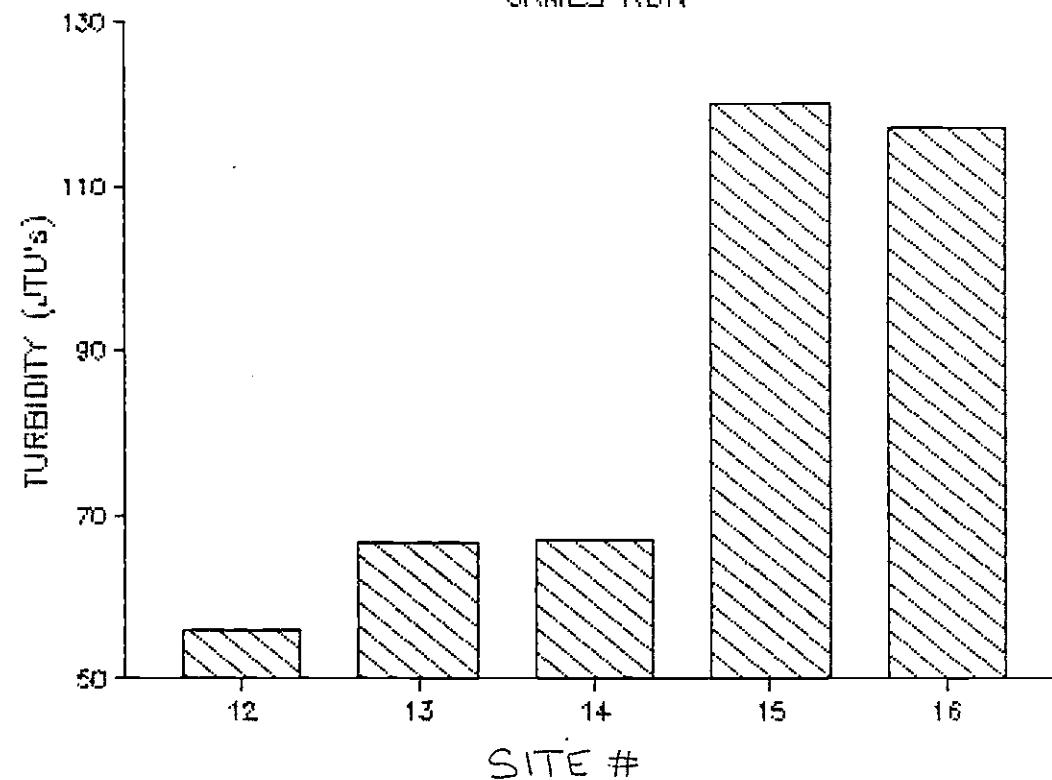
AVERAGE TURBIDITY
WINTERS RUN



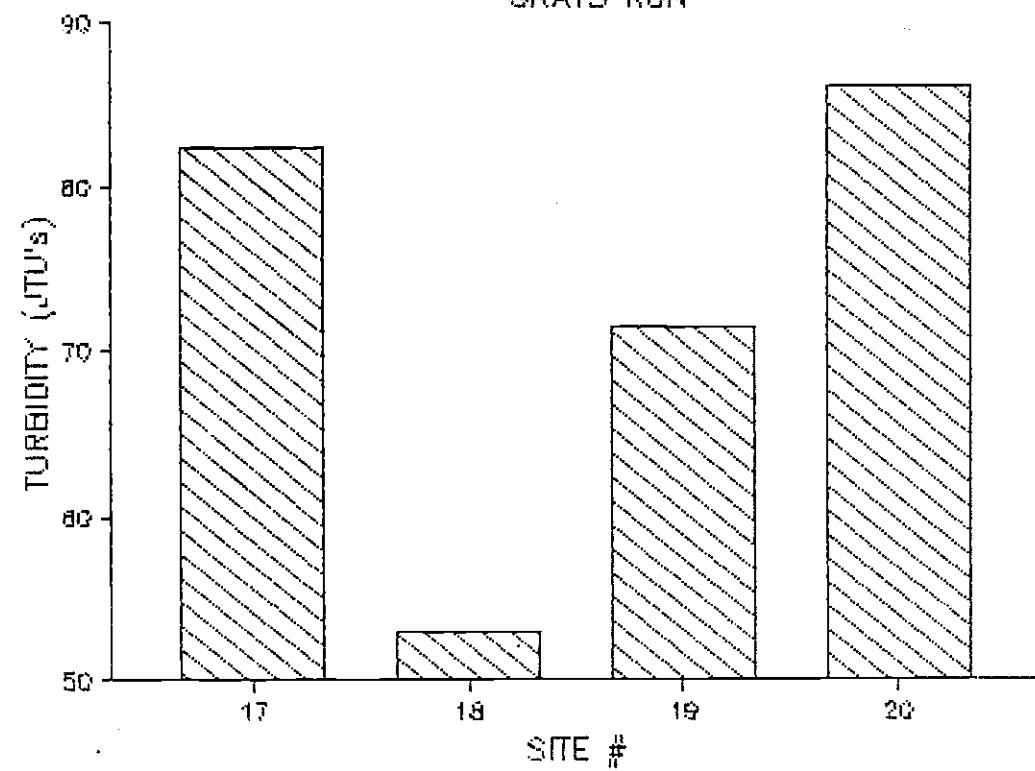
AVERAGE TURBIDITY
BYNUM RUN



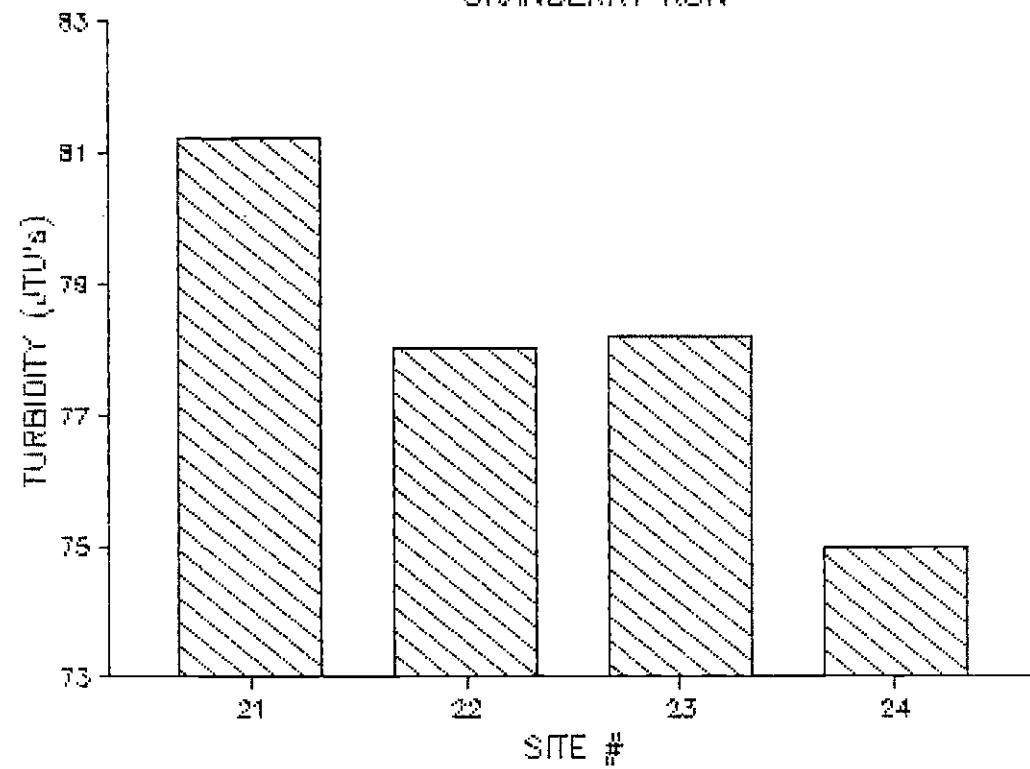
AVERAGE TURBIDITY
JAMES RUN

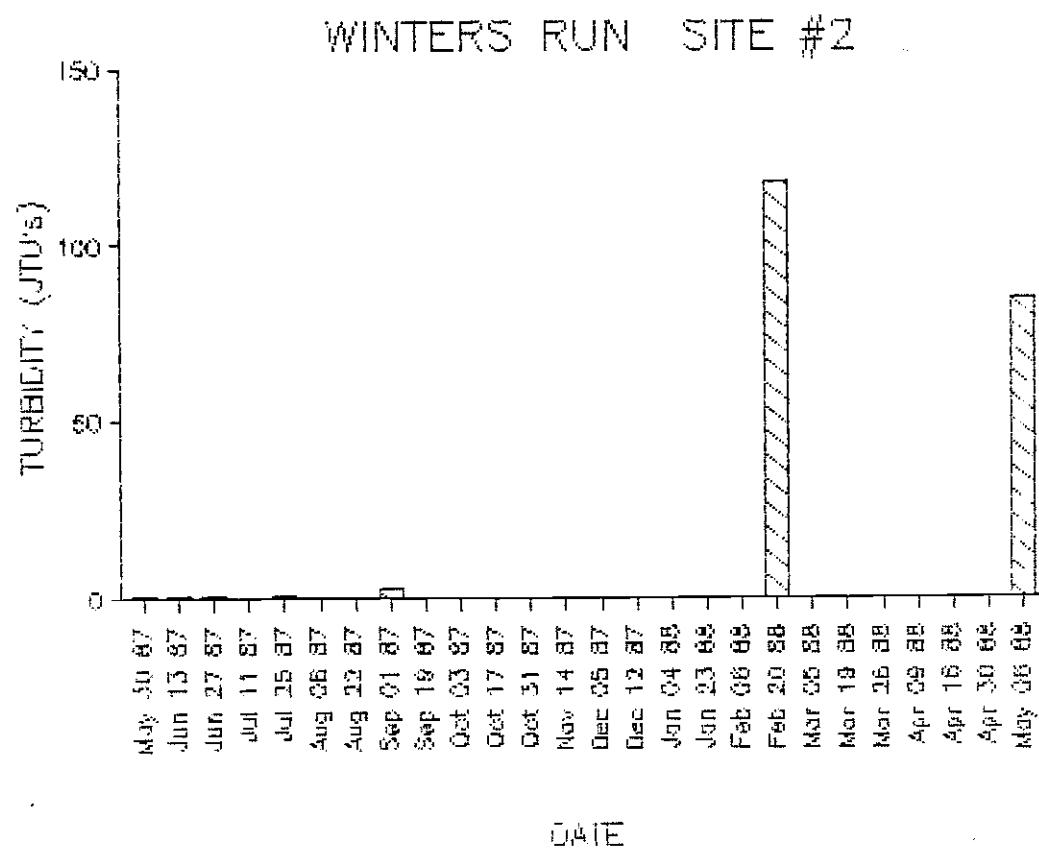
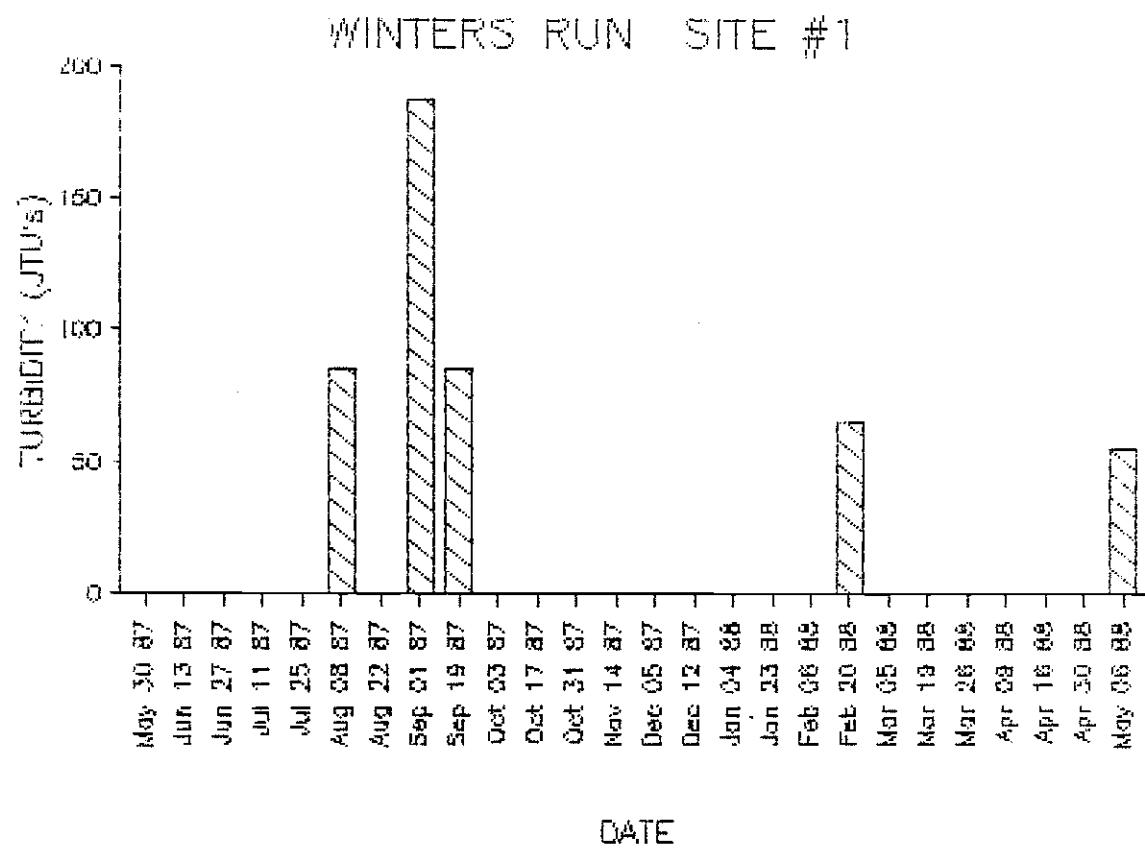


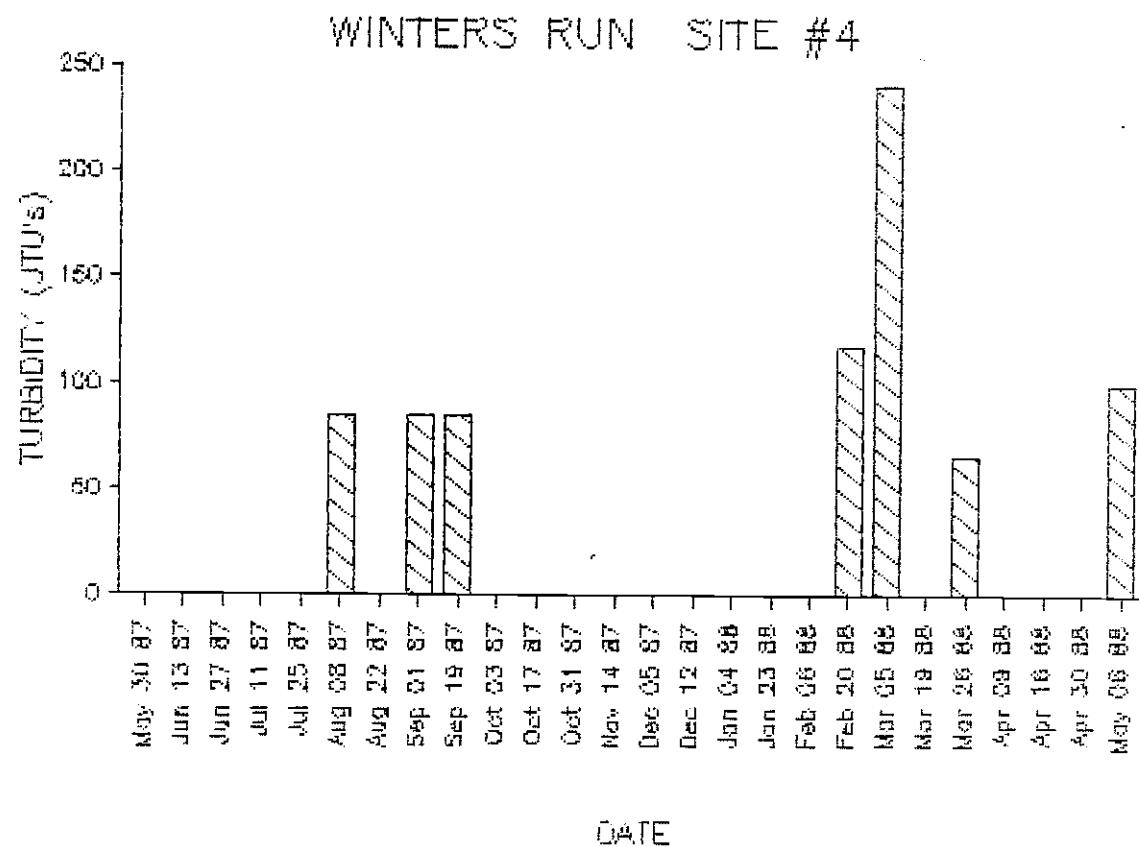
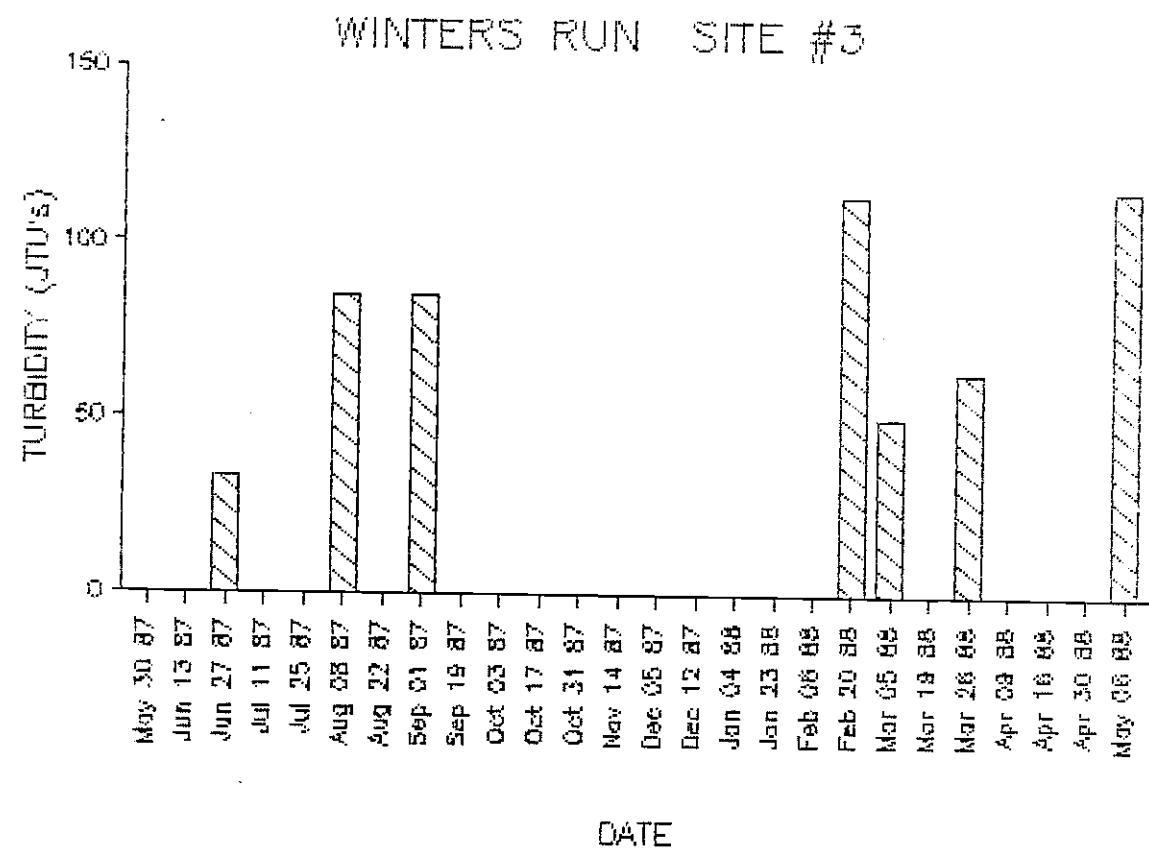
AVERAGE TURBIDITY
GRAYS RUN

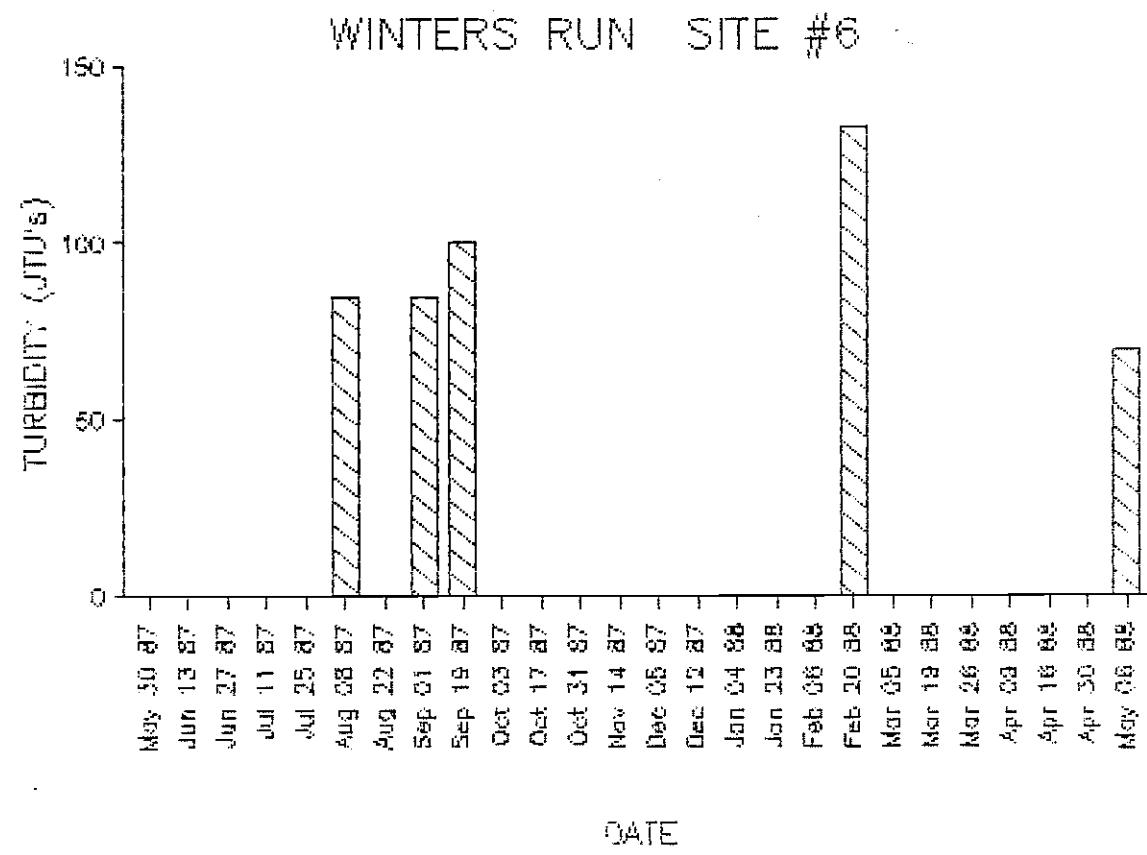
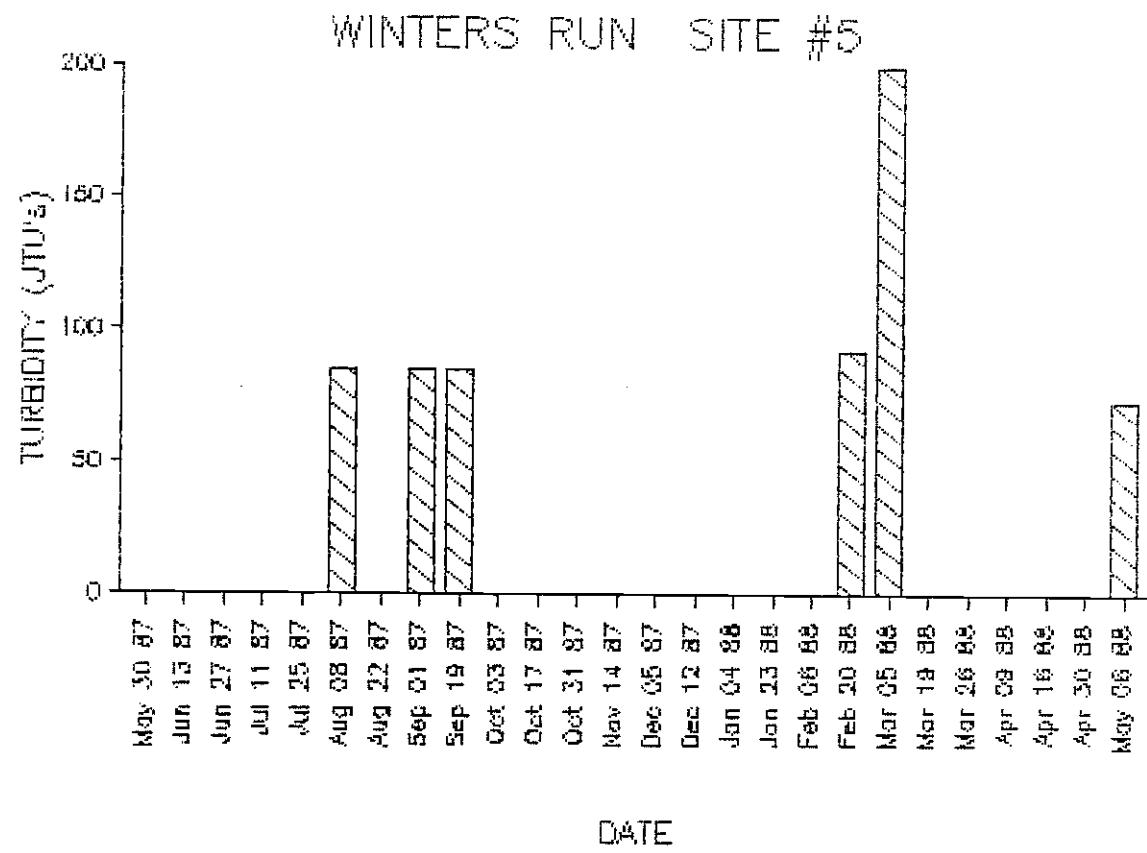


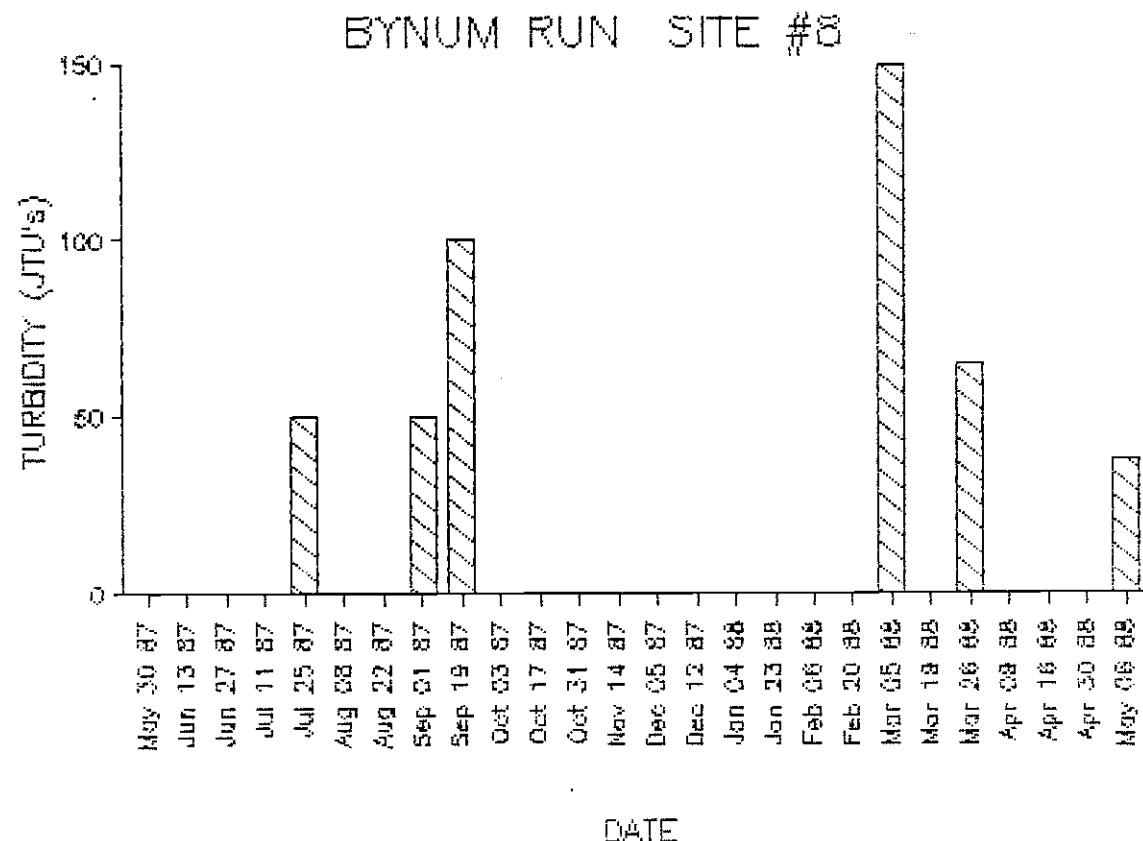
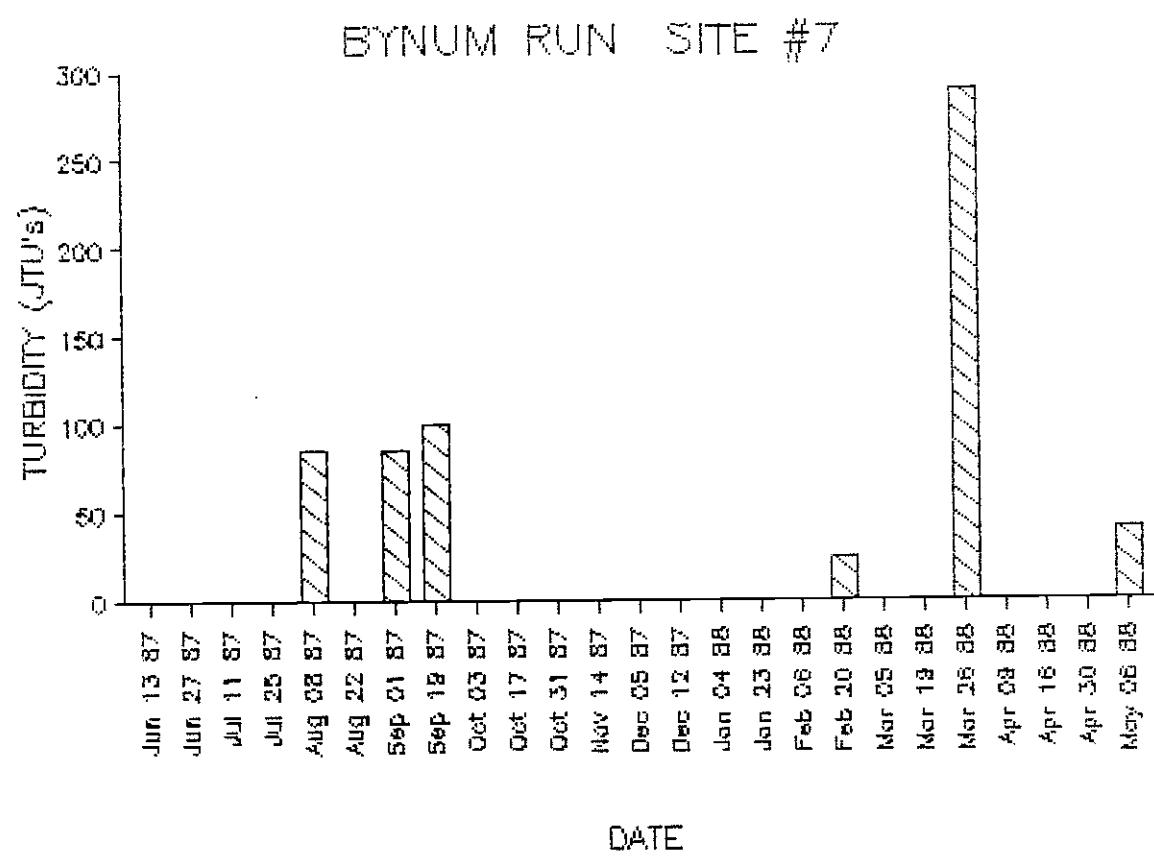
AVERAGE TURBIDITY
CRANBERRY RUN

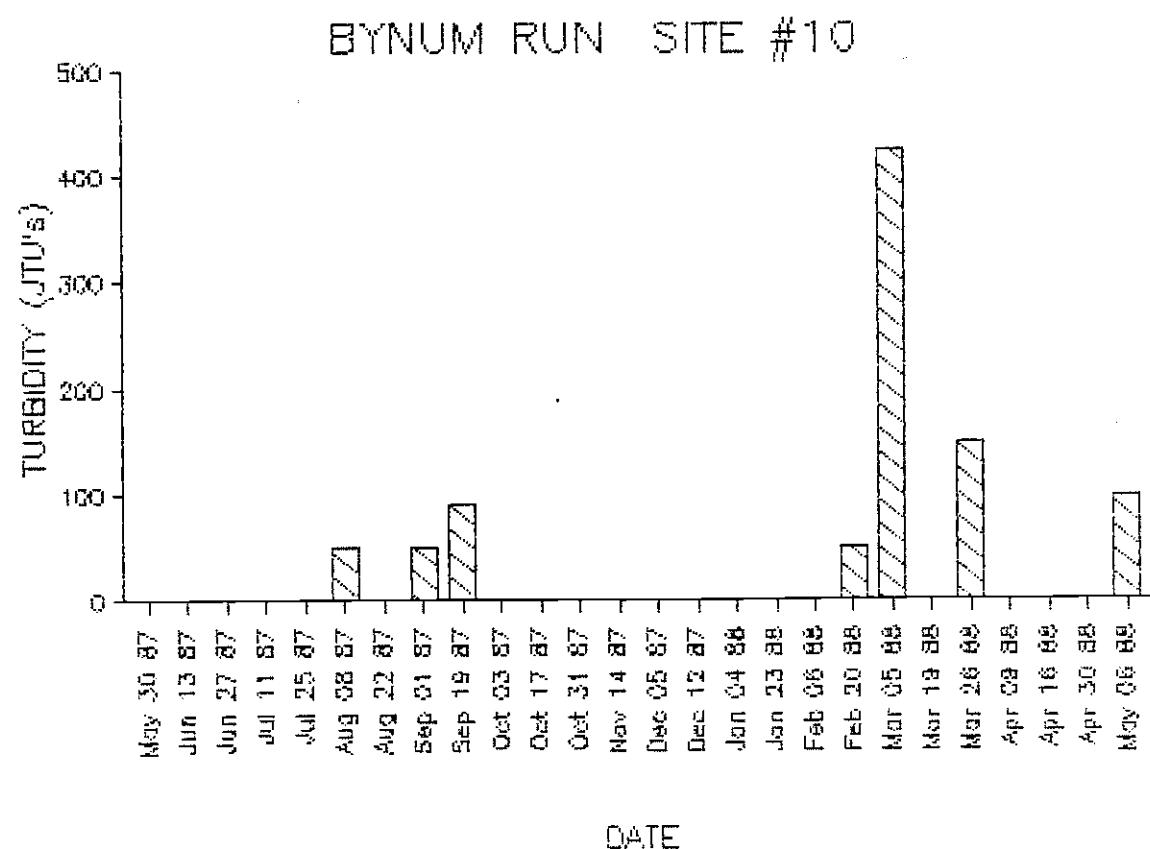
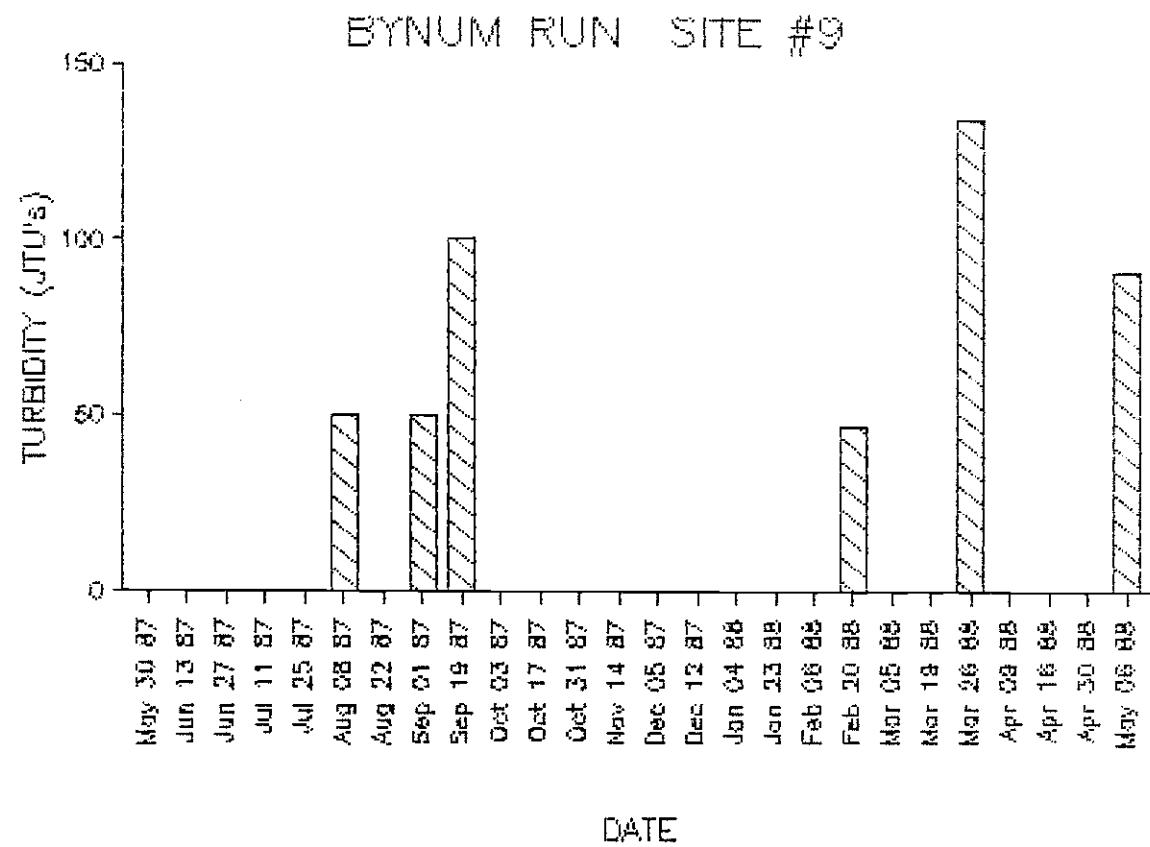




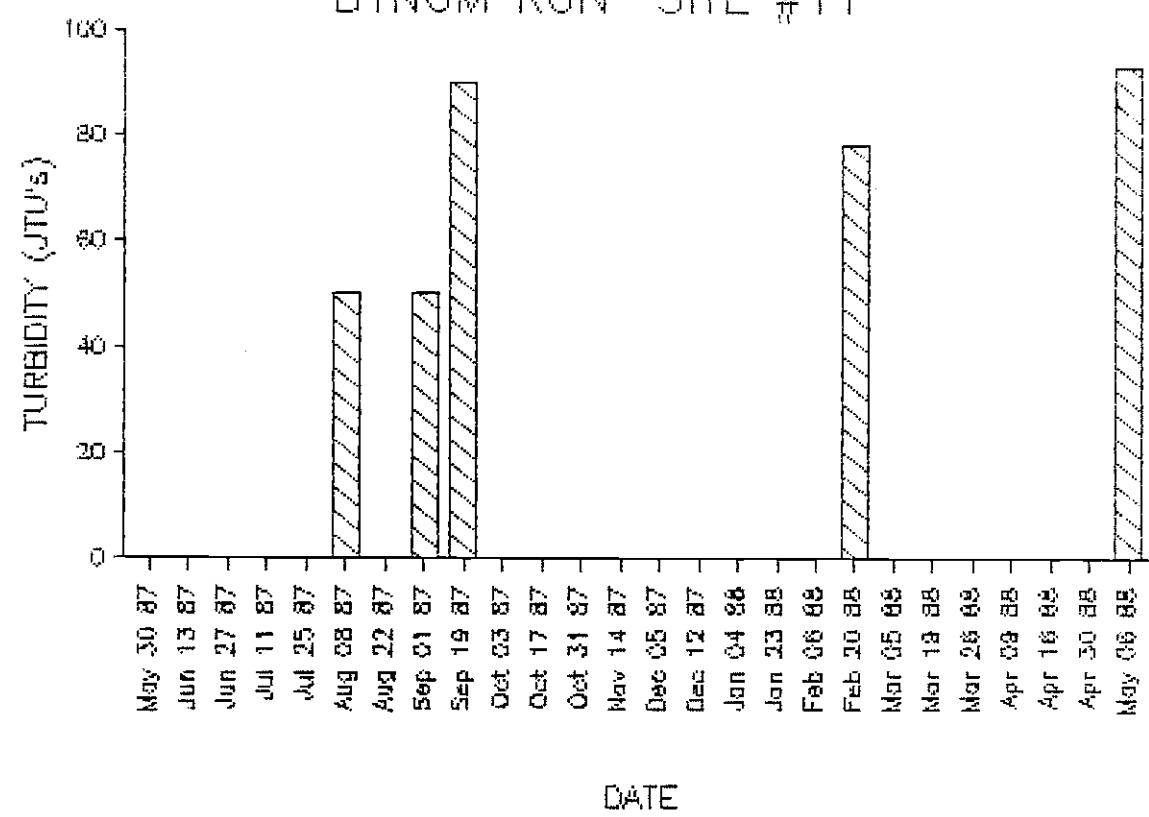


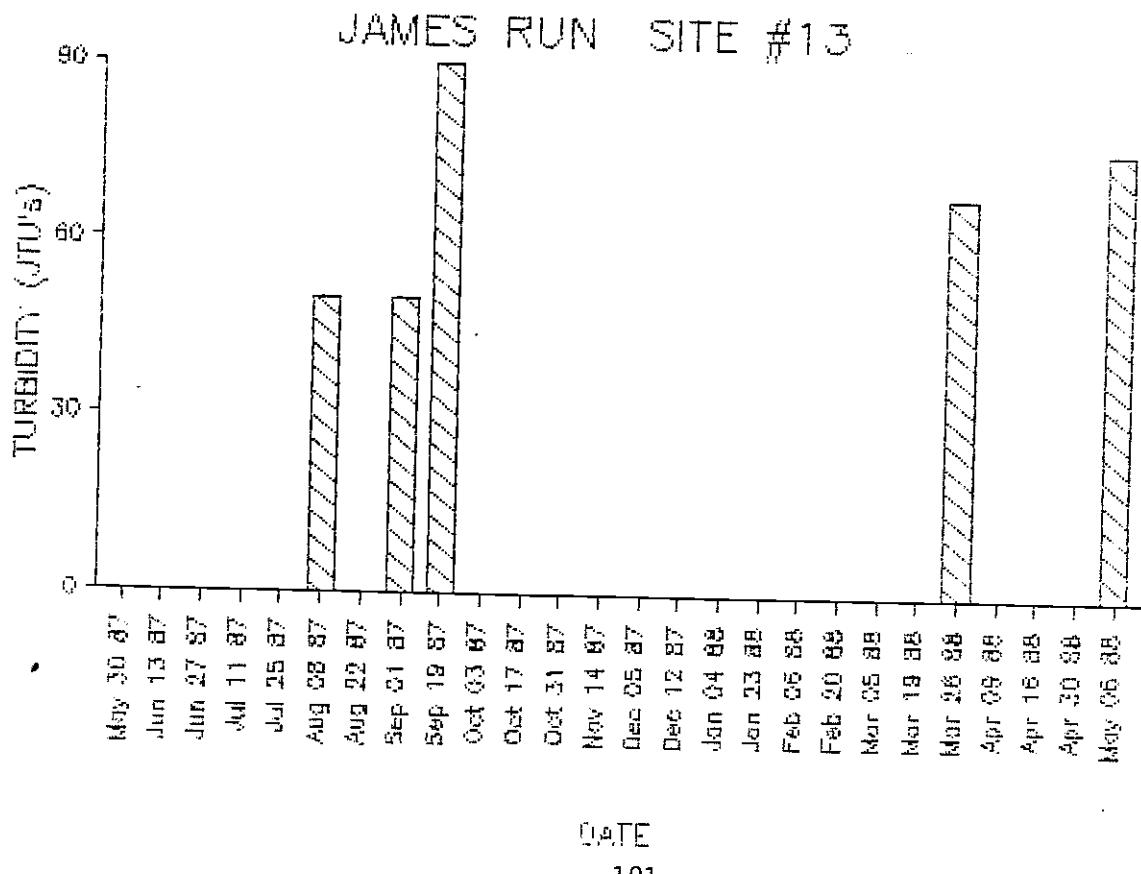
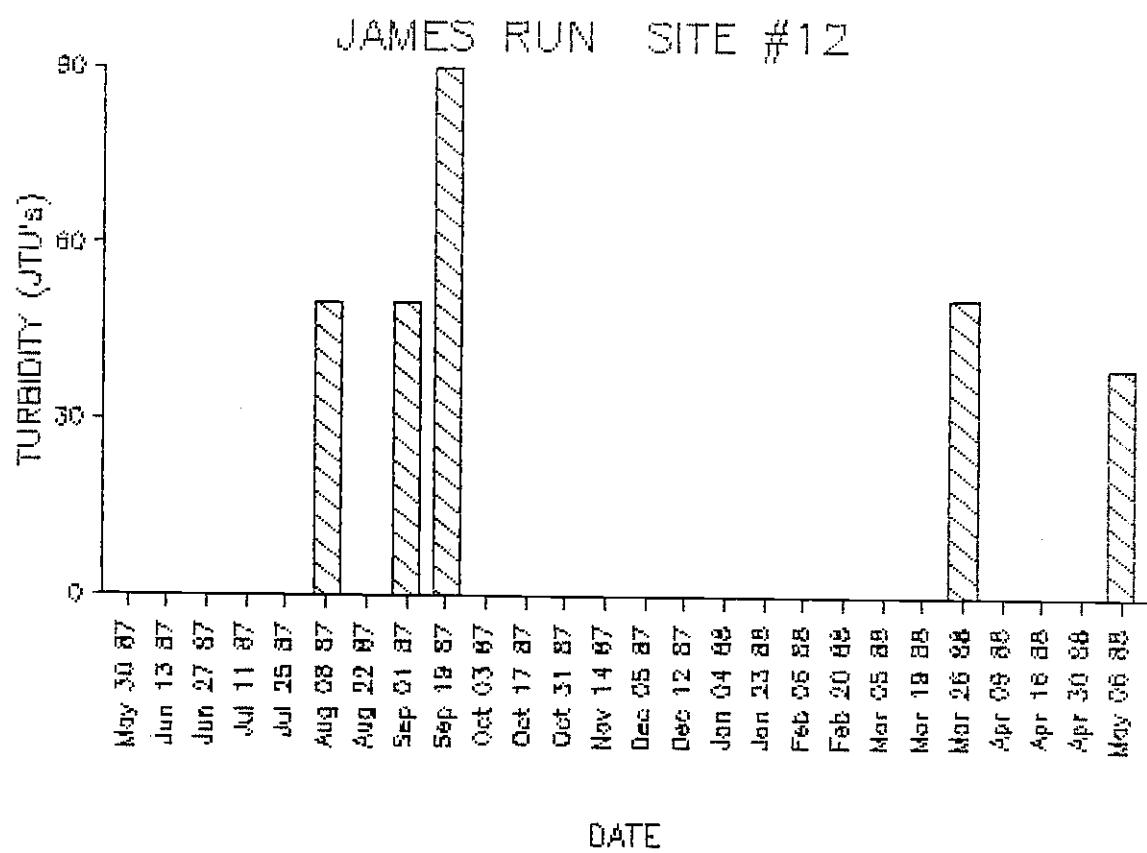




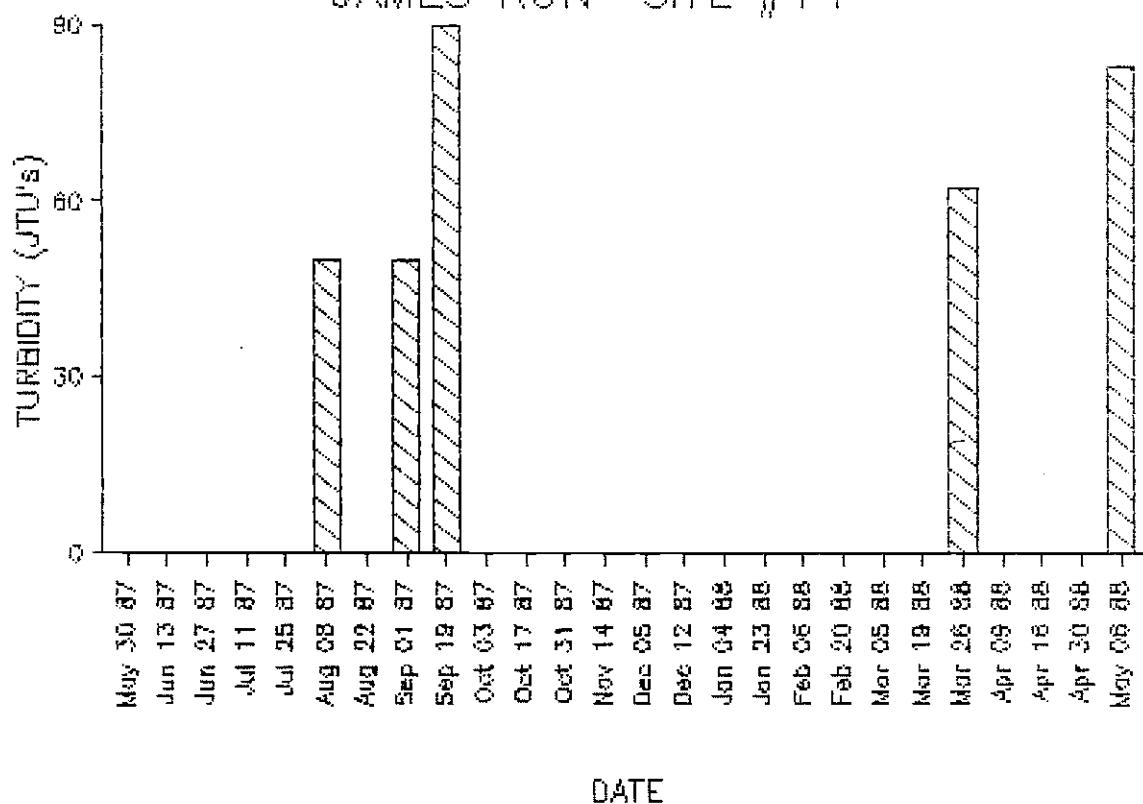


BYNUM RUN SITE #11

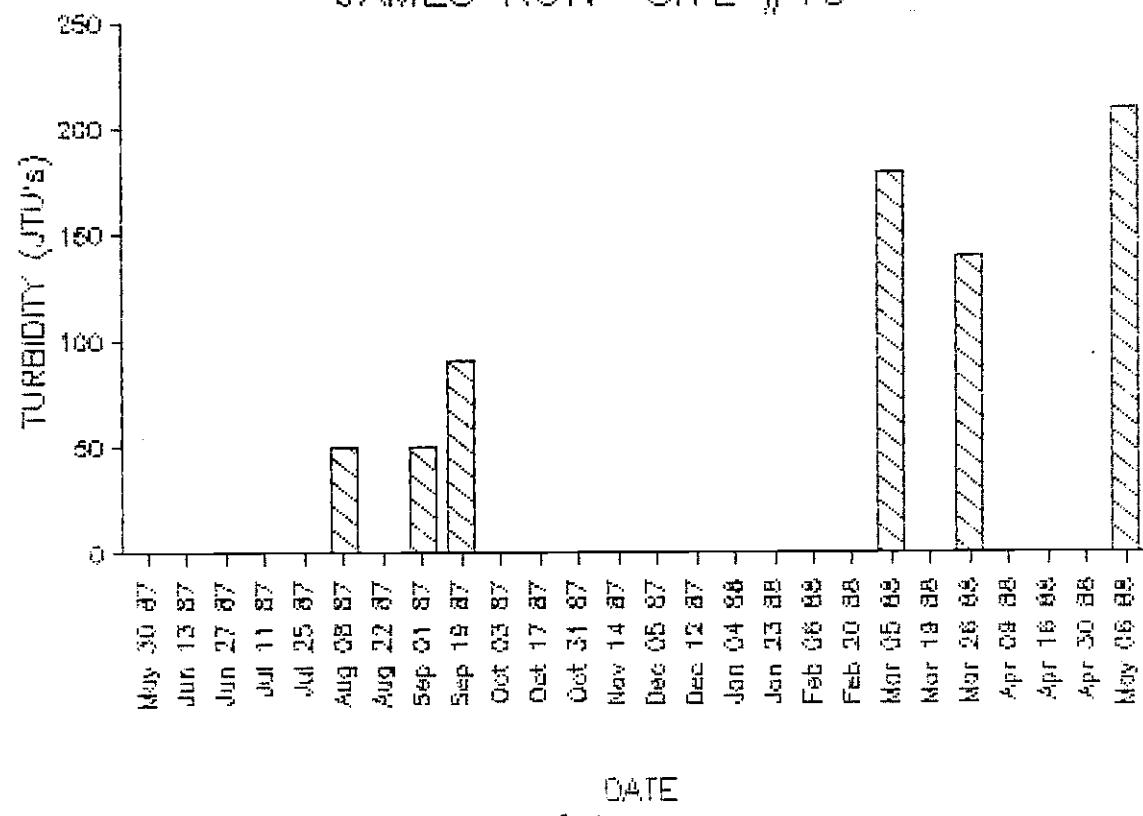




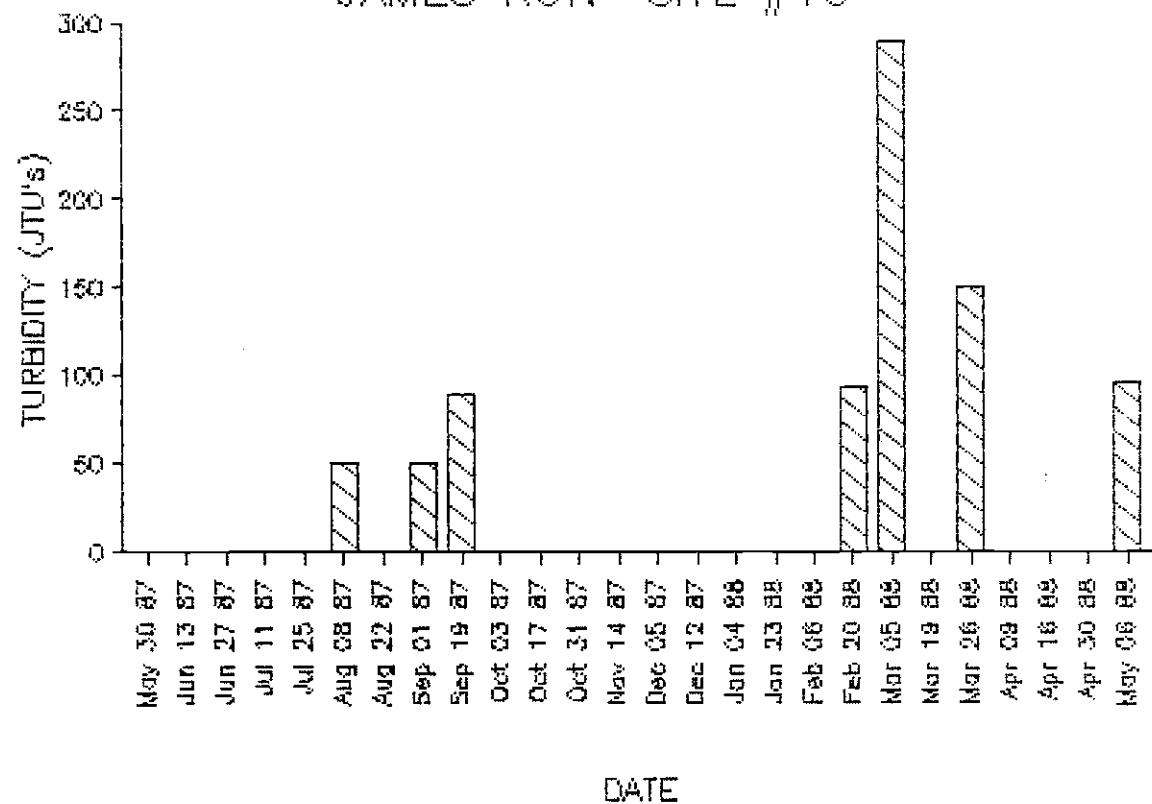
JAMES RUN SITE #14



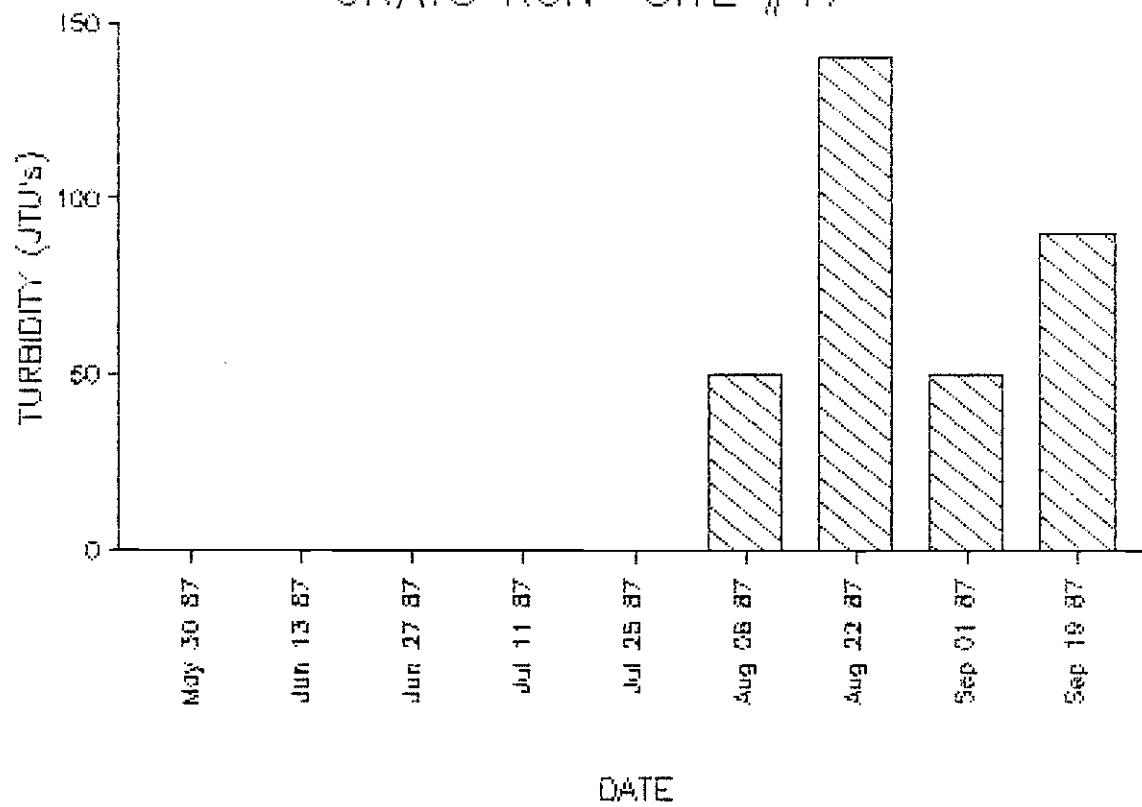
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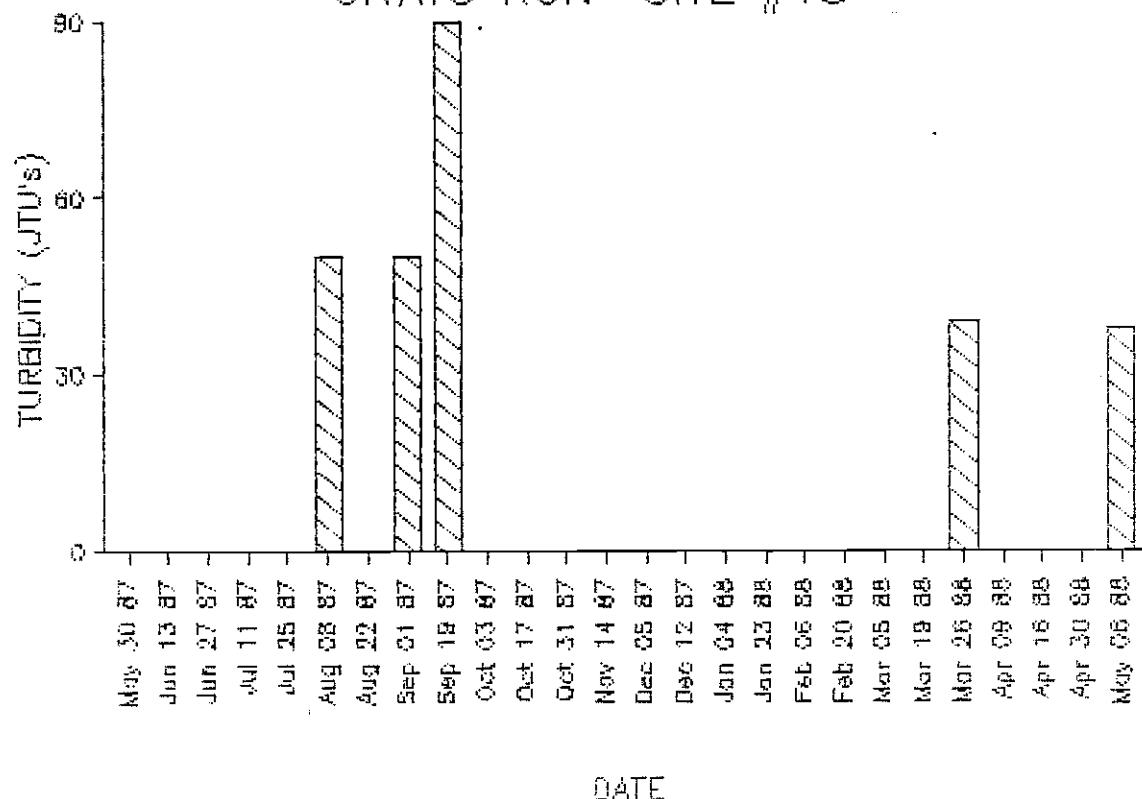
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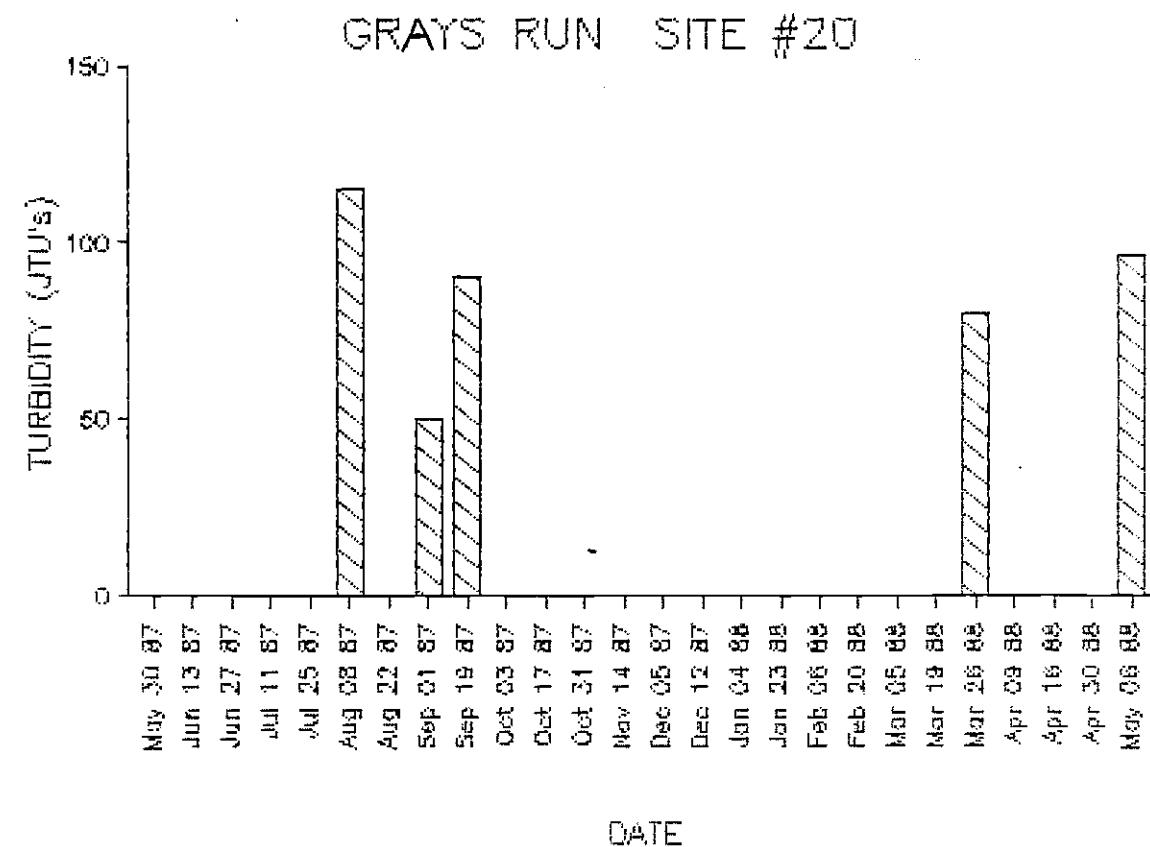
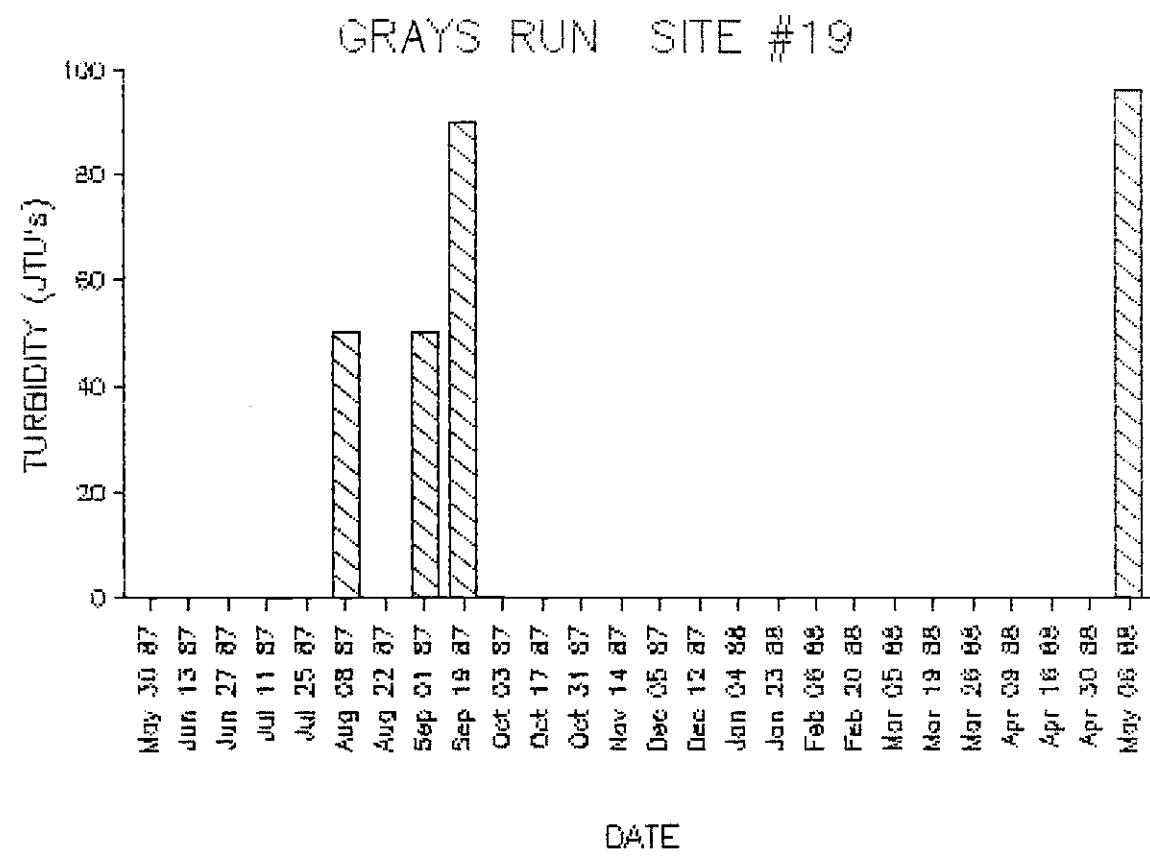


GRAYS RUN SITE #17

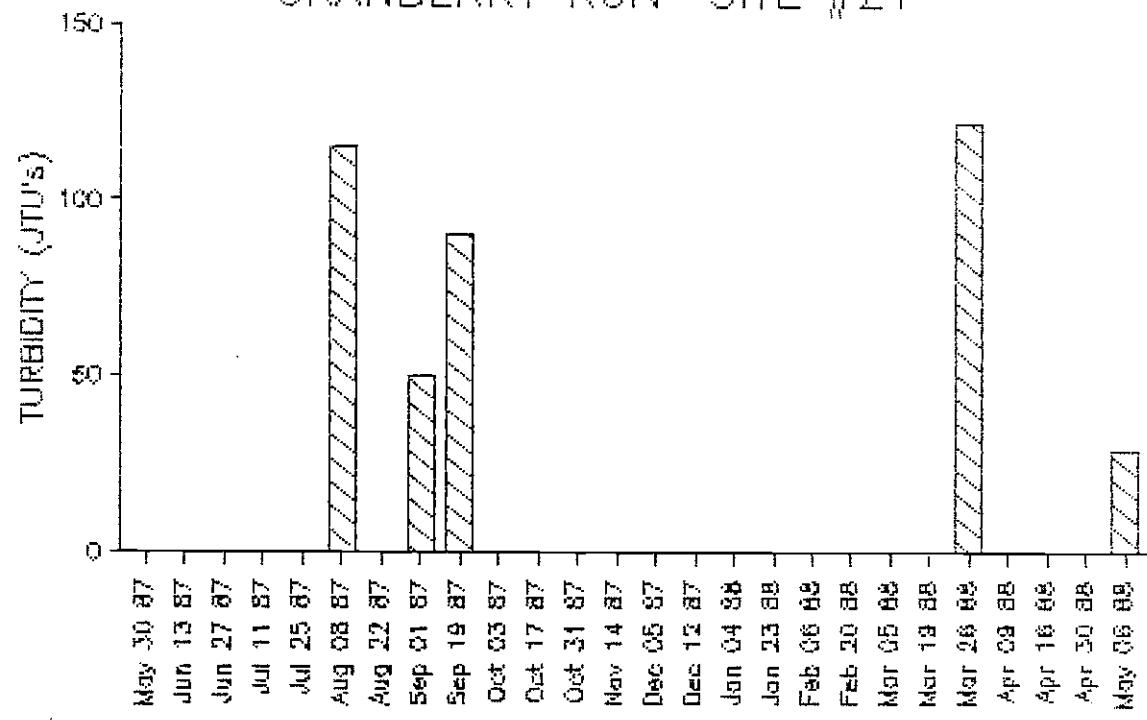


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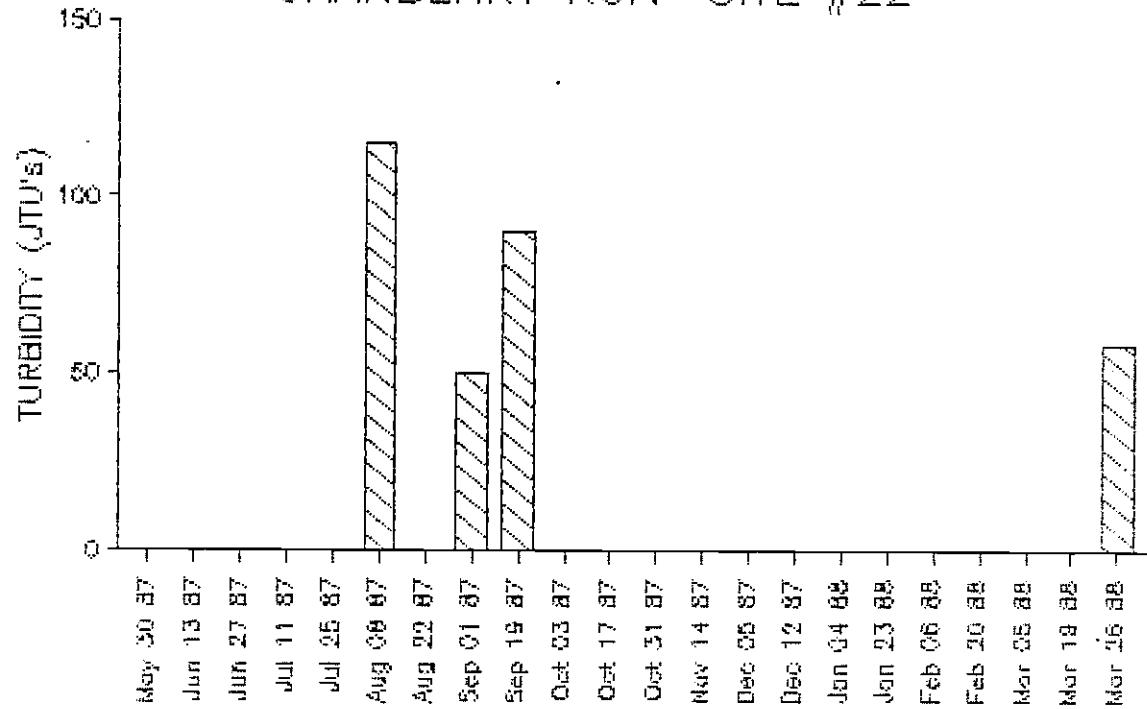




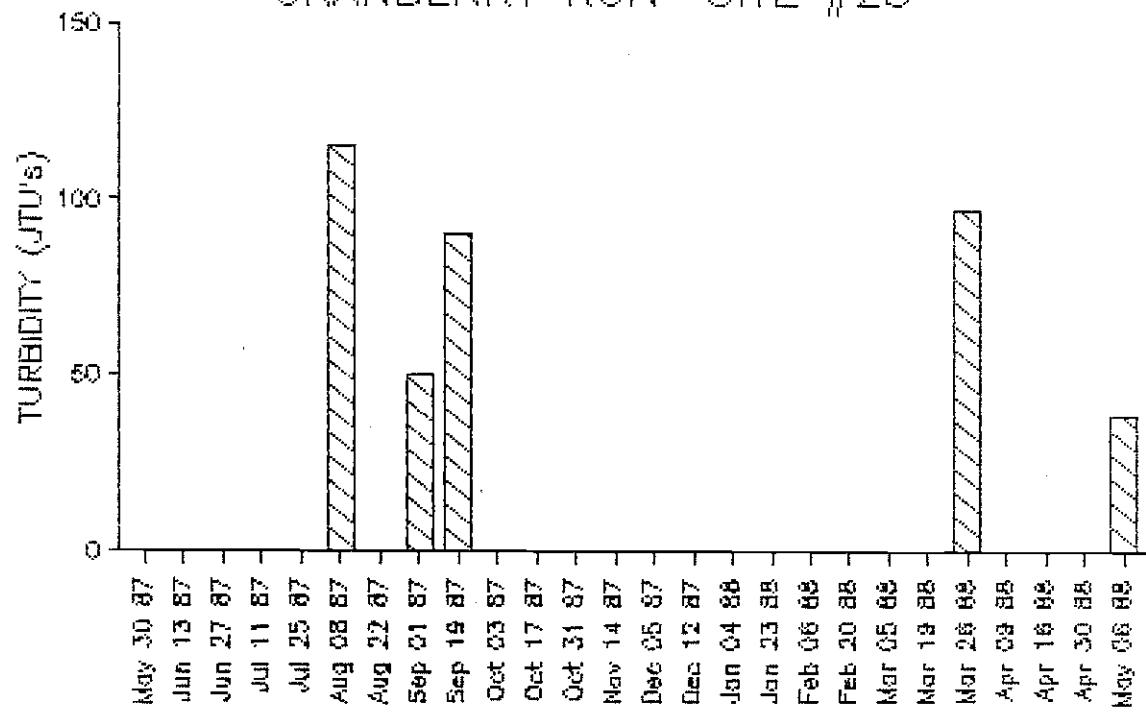
CRANBERRY RUN SITE #21



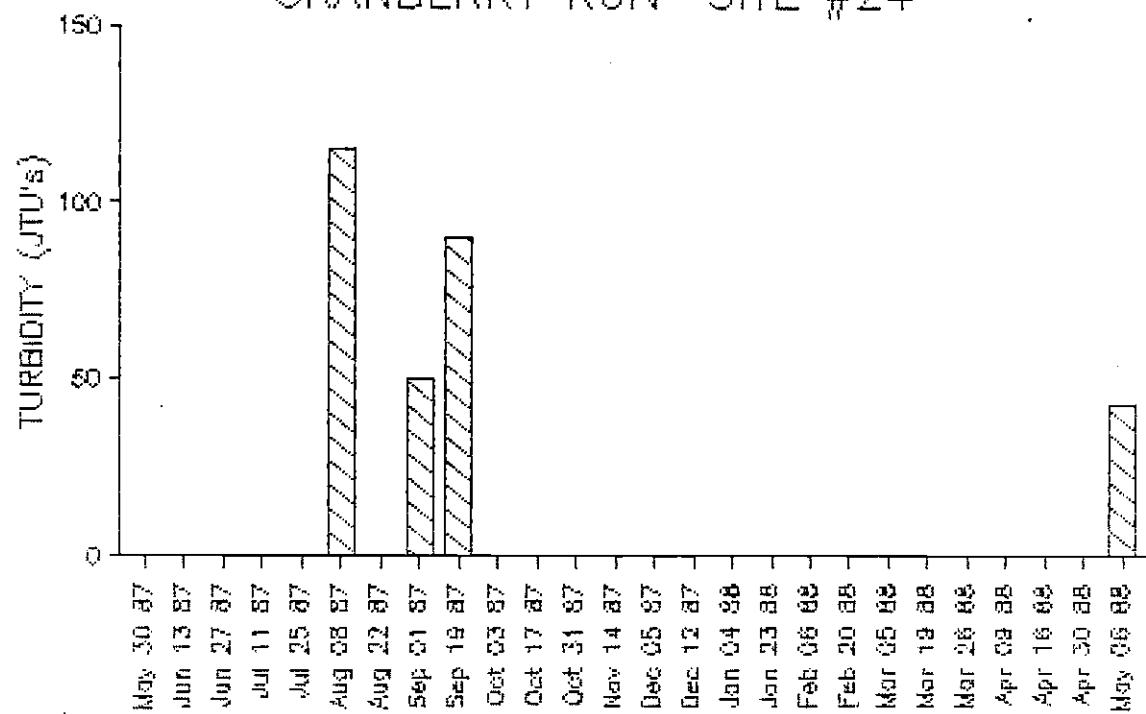
CRANBERRY RUN SITE #22



CRANBERRY RUN SITE #23



CRANBERRY RUN SITE #24



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